PB-238 445

ATMOSPHERIC EMISSIONS FROM ASPHALT ROOFING PROCESSES

R. W. Gerstle

PEDCo-Environmental, Incorporated

Prepared for:

National Environmental Research Center

Ocotber 1974

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TECHNICAL REPORT DATA

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1. REPORT NO. EPA-650/2-74-101	2.	PB 238 445
4. TITLE AND SUBTITLE Atmospheric Emissions from Asphalt Roofing Processes		5. REPORT DATE October 1974
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) R.W. Gerstle		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS PEDCo-Environmental, Inc. Atkinson Square (Suite 13) Cincinnati, Ohio 45246		10. PROGRAM ELEMENT NO. 1AB015; ROAP 21AXM-011
		11. CONTRACT/GRANT NO. 68-02-1321 (Task 15)
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development NERC-RTP, Control Systems Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Final; 12/73-9/74
		14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution	Gases	Air Pollution Control	13B, 07D
Asphalt Plants		Stationary Sources	13H
Roofing		Polycyclic Organic Matter	13C
Polycyclic Compounds			07C
Carbon Monoxide		Particulates	07B
Hydrocarbons		Felt Saturation	

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 160
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE $6.25-2.25

EPA Form 2220-1 (9-73)

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by

R. W. Gerstle

PEDCo-Environmental, Inc.
Atkinson Square (Suite 13)
Cincinnati, Ohio 45246

Contract No. 68-02-1321 (Task 15)
ROAP No. 21AXM-011
Program Element No. 1AB015

EPA Project Officer: Belur N. Murthy

Control Systems Laboratory
National Environmental Research Center
Research Triangle Park, North Carolina 27711

Prepared for

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

October 1974

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ABSTRACT

Asphalt roofing manufacturing processes and the types of air pollution control devices applied to them are described. Quantitative data on controlled and uncontrolled particulate and gaseous emissions, including polycyclic compounds, from the asphalt blowing and felt saturating processes are provided. Information on plant locations, production rates, and industry growth is included. Total uncontrolled particulate emissions from felt saturating, consisting largely of organic particulate compounds, averaged from 3.9 to 8.7 lb per ton of saturated felt; CO and gaseous hydrocarbons were also emitted. Control devices reduced these emissions by about 50%. Seven identified polycyclic organic compounds accounted for 0.0003% of the particulate matter both before and after control. Particulate matter was mostly smaller than 1 micron. For asphalt blowing operations controlled by fume incineration, particulate emissions amounted to 0.3 to 3.1 lb per 1000 gal. (0.075 to 0.79 lb per ton) of asphalt; polycyclic organic matter ranged between 0.0008 and 0.0019% of the total particulate; CO and gaseous hydrocarbons are also emitted. These data indicate that a well-operated plant equipped with available control devices does not have a major impact on ambient air concentrations.

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ACKNOWLEDGMENTS

Dr. Belur Murthy of the Control Systems Laboratory, U.S. Environmental Protection Agency, was EPA Project Officer, providing technical review and direction. Mr. Richard Gerstle, Project Manager for PEDCo-Environmental Specialists, Inc., directed and participated in the preparation of this report. Mr. William DeWees directed the field sampling and analytical effort that comprised a major part of this study.

In addition, some of the major asphalt roofing manufacturers, especially Celotex Division of Jim Walther Corporation and Johns-Manville Corporation, cooperated in providing information for this study.

SUMMARY AND CONCLUSIONS

The asphalt roofing industry as defined under Standard Industrial Classification 2952 comprises establishments primarily engaged in manufacturing asphaltic roofing products in roll and shingle form. There are approximately 230 establishments in the country which produced a total of 9.4 million short tons of product in 1972 valued at $700 million. The industry is related to the building industry and in recent years has been growing at a rate of 3 to 4 percent per year. Raw material supplies and costs are closely tied to the petroleum refining industry.

The manufacture of asphalt roofing products consists of impregnating a felt with specially prepared, heated asphalt. This is accomplished by passing a continuous sheet of the felt (usually heavy paper) over rollers in a saturator which is a long narrow trough containing asphalt at 400-450°F. This dipping causes the asphalt to coat the felt on both sides. The saturated felt may be coated with granules and cut into shingles, or shipped in roll form. Product specifications dictate the weight (thickness) and exact type of felt, and the asphalt melt point. Asphalt used in the saturator is prepared by blowing air through it to reduce its volatile content and raise its melting point. This batch operation is performed in vertical tanks or stills with asphalt at a temperature of 430-500°F. Many roofing plants buy asphalt which has already been blown, usually at an oil refinery.

Atmospheric emissions of both gaseous and particulate organic compounds occur from the blowing and saturating processes. These organic compounds include small amounts of particulate polycyclic organic matter (PPOM). In addition, gaseous emissions of CO, aldehydes, and sulfur compounds also occur. The quantity of these emissions depends on the type of product and on the type of emission control equipment.

Emissions of particulate and polycyclic particulate matter (PPOM) are summarized in Table 1, and are based on measured emission data obtained during this study.

Table 1. AVERAGE PARTICULATE AND PPOM EMISSIONS

Operation	**Particulate, lb/ton of felt**		**PPOM,[a] % of particulate x 10^{-4}**	
	Uncontrolled	Controlled	Uncontrolled	Controlled
Saturating	6.3	2.7	3.0	3.2
Blowing	4.5	0.32	1.65	13

[a] **Seven identified compounds only. BaP is approximately 10% of this quantity.**

These data show particulate emissions of approximately 6.3 and 2.7 pounds per ton of saturated felt for saturating operations without controls and with controls. Higher control efficiencies can be expected when control equipment is operated under optimum conditions. Approximately 50% by weight of the particulate emissions are less than one micron in size.

PPOM accounted for 0.0003% of the collected particulate matter. PPOM was reduced by passage through control devices used to reduce particulate emissions. This reduction was in direct proportion to the particulate reduction.

Saturator emissions are controlled by a variety of devices including afterburners, High Energy Air Filters (HEAF), and low voltage electrostatic precipitators. Operating costs for saturator control devices vary widely depending on the type of device and are in the range of $0.26 to $3.1 per ton of saturated felt. When afterburners are used, the heat generated is partially used to preheat asphalt.

Particulate emission rates from blowing operations are highly variable and increase when high-melt-point asphalt is produced.

These emissions averaged 4.5 and 0.3 pounds per ton of saturated felt for the uncontrolled and controlled conditions respectively.

PPOM emissions from blowing amounted to 0.0013% of the total particulate after a fume incinerator.

Practically all asphalt blowing operations are controlled by direct-fired fume incinerators. These devices are frequently process heaters used to preheat the asphalt before gas or light oil are used as fuels.

Emissions of carbon monoxide and gaseous hydrocarbons are summarized in Table 2.

Table 2. GASEOUS EMISSIONS

(lb/ton of saturated felt)

	CO		HC[a]	
Process	Uncontrolled	Controlled	Uncontrolled	Controlled
Saturating	2.6	1.8	0.55	0.49
Blowing	0.16	1.7	0.43	0.4

a) Total gaseous hydrocarbons expressed as methane.

NOTE: Range values are averages of test data.

These data show that CO averaged 6.3 and 2.7 pounds per ton of saturated felt before and after control equipment. Gaseous hydrocarbons averaged approximately 0.5 pound per ton of felt. Aldehydes were present in small amounts and average less than 0.05 pound per ton. Fume incinerators were only partially effective in reducing these pollutants.

Blowing operations yielded emissions similar to those from felt saturating. In addition, hydrogen sulfide in the range of 0.3 to 0.7 part per million was present in the uncontrolled gas stream. After passage through a fume incinerator the H_2S was reduced to less than 0.02 ppm.

Sulfur dioxide emissions from blowing operations vary directly with the asphalt's sulfur content, and during one test amounted to 0.5% of the sulfur present in the asphalt.

Particulate emissions from other processes associated with roofing include those from sand drying and application of surfacing agents. These emissions are readily controlled by available equipment and are not usually a problem.

Ambient air concentrations were calculated utilizing a single point dispersion model; and emission parameters determined from this study. These calculations show that asphalt roofing plants with emission controls would not be expected to cause primary ambient air standards for particulate, CO and gaseous hydrocarbons to be exceeded under normal operating conditions. Particulate emissions from uncontrolled plants could however, cause excessive ambient air concentrations. Odors also occur from poorly controlled plants.

Ambient air standards for PPOM compounds do not exist. However, based on available information, it does not appear that roofing plants with typical particulate controls are a major contributor of these compounds to the ambient air.

° CONVERSION FACTORS °

ENGLISH UNITS TO METRIC UNITS

Multiply	by	To Obtain
Atmosphere	760.0	millimeters of mercury
BTU (British Thermal Units)	252.0	gram calories
Cubic foot	28.32	liters
Foot	30.48	centimeter
Gallons (US)	3.785	liters
Grain	0.065	gram
Grains/cubic foot	2288	milligrams/cubic meter
Horsepower	0.7457	kilowatts
Pound	435.6	grams
Tons (long)	1016	kilogram
Tons (short)	907.0	kilogram

1.0 INTRODUCTION

This report presents results of a study to characterize and measure atmospheric emissions from asphalt roofing manufacturing processes and related information on control equipment and the impact of emissions on the ambient air in the vicinity of asphalt roofing plants.

1.1 TECHNICAL OBJECTIVES

The primary objectives of this study were to measure the atmospheric emissions of particulate polycyclic organic matter (PPOM) from asphalt roofing manufacturing processes; to describe the demographic parameters of this industry, such as size, location, and growth patterns; to determine the impact of emissions on the ambient air; and to predict the degree of control required to maintain levels of pollutants in the ambient air. The characterization of PPOM included quantitative measurements of effluent gas streams to determine concentrations of selected polycyclic organic compounds before and after control devices. Two asphalt blowing and two saturating operations, representing the major process segments, were tested to determine emission rates. Emission rates were related to various process variables to provide a basis for estimating emissions from other plants within this industry.

1.2 INDUSTRY CLASSIFICATION

The asphalt roofing industry, Standard Industrial Classification 2952, comprises establishments engaged primarily in manufacturing asphalt and tar roofing products in roll and shingle form, either smooth or faced with grit, and in manufacturing roofing cements and coatings. Products within these categories are listed in Table 1.1.

Table 1.1 ASPHALT ROOFING PRODUCTS CATEGORIES

A) Roll roofing and cap sheets
    Smooth-surfaced
    Mineral-surfaced

B) Strip shingles
    Standard
    Self-sealing

C) Individual shingles

D) Asphalt sidings
    Roll form
    Shingle form

E) Insulated siding

F) Saturated felts
    Asphalt
    Tar

G) Adhesive compounds
    Built-up roofing
    Damp proofing and waterproofing

H) Bituminous cement (asphalt putty)

1.3 ACQUISITION OF INFORMATION

Process descriptions were formulated by consulting the technical literature, visiting asphalt roofing plants, and conversing with various industry personnel and control equipment vendors. Statistical data were obtained largely from the U.S. Government Department of Commerce and the Bureau of Mines. Plant locations were determined to the extent possible from listings of the Asphalt Roofing Manufacturer's Association, Dun & Bradstreet, and EPA's emission data survey listings. It is believed that all major manufacturing plants as of mid-1973 were identified in these surveys.

Equipment vendors were contacted to obtain information on efficiencies and costs of controls and related information as applied to asphalt roofing.

Some emission data were obtained from the literature and from vendor's information. Since these data usually were not related to process parameters, their usefulness was limited. Therefore, emission data for this report were obtained mainly from field tests conducted as part of this project at two asphalt blowing and two saturator operations. Standard stack sampling methods as specified in the Federal Register were used in the emission tests wherever possible. The particulate sampling train (EPA Method 5) included impingers contained in an ice-water bath and a final "cold" filter to trap PPOM compounds. All PPOM analyses were performed with gas chromatographic separation and mass spectrophotometric detection by

Battelle Laboratories in Columbus, Ohio. Emissions were sampled under two distinct operating conditions at each plant, and samples were collected before and after the control device.

2.0 INDUSTRY TRENDS AND ECONOMIC FACTORS

2.1 PRODUCT SHIPMENTS

Shipments of asphalt roofing products totaled 9.4 million short tons* in 1972, as shown in Table 2.1. Asphalt roofing represented 89.7 percent of the total; saturated felts, 9.6 percent; and asphalt and insulated siding, about 0.7 percent. These products were valued at over $700 million.[2.1]

According to the Census of Manufacturers, there were 233 asphalt roofing establishments in 1972.[2.2] These establishments averaged about 67 employees and had average shipments of approximately $4.3 million each, for a total of $1.004 billion in shipments. Table 2.2 shows the size distribution of these firms in 1967 and the average value of shipments for each size class. The current size distribution of plants, similar to the 1967 distribution, indicates a wide and fairly uniform distribution of plants within each size category.

2.2 INDUSTRY TRENDS

2.2.1 Historical Sales Rates

Shipments by this industry have been rather erratic from year to year. The overall trend has been upward, with the shipment tonnage increasing at a rate of about 3 percent per year, as shown in Figure 2.1.

---

* Conversion table from English to metric is on page 6.

Table 2.1 ANNUAL SHIPMENTS OF ASPHALT PRODUCTS[2.1]

(tons)

Product code	Product[a]	Year									
		1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
29523 11	**Asphalt roofing, Total**	5,441,313	6,041,022,	6,124,269	5,751,881	6,460,334	6,525,205	7,035,595	6,877,567	7,951,774	8,389,592
	Asphalt sidings, Total	42,906	38,721	32,778	29,141	24,580	21,744	20,611	13,604	9,620	6,997
29523 35	**Insulated siding, all types and finishes**	96,786	79,777	57,121	59,311	43,327	39,874	35,432	32,149	35,531	65,517
	Saturated felts, Total	989,557	995,128	979,632	879,581	876,019	874,998	919,687	848,262	915,556	895,062
	United States, Total	6,570,562	7,154,648	7,193,800	6,719,914	7,404,260	7,458,889	8,011,325	7,771,582	8,912,481	9,357,168

[a] Does not include asbestos-based materials.

Table 2.2 PRODUCTION OF ASPHALT SATURATED PRODUCTS BY SIZE CLASS, 1967[2.3]

Number of employees	Number of establishments
1 to 4	33
5 to 9	22
10 to 19	33
20 to 49	46
50 to 99	44
100 to 249	42
250 to 499	4
500 to 999	2
Total	226

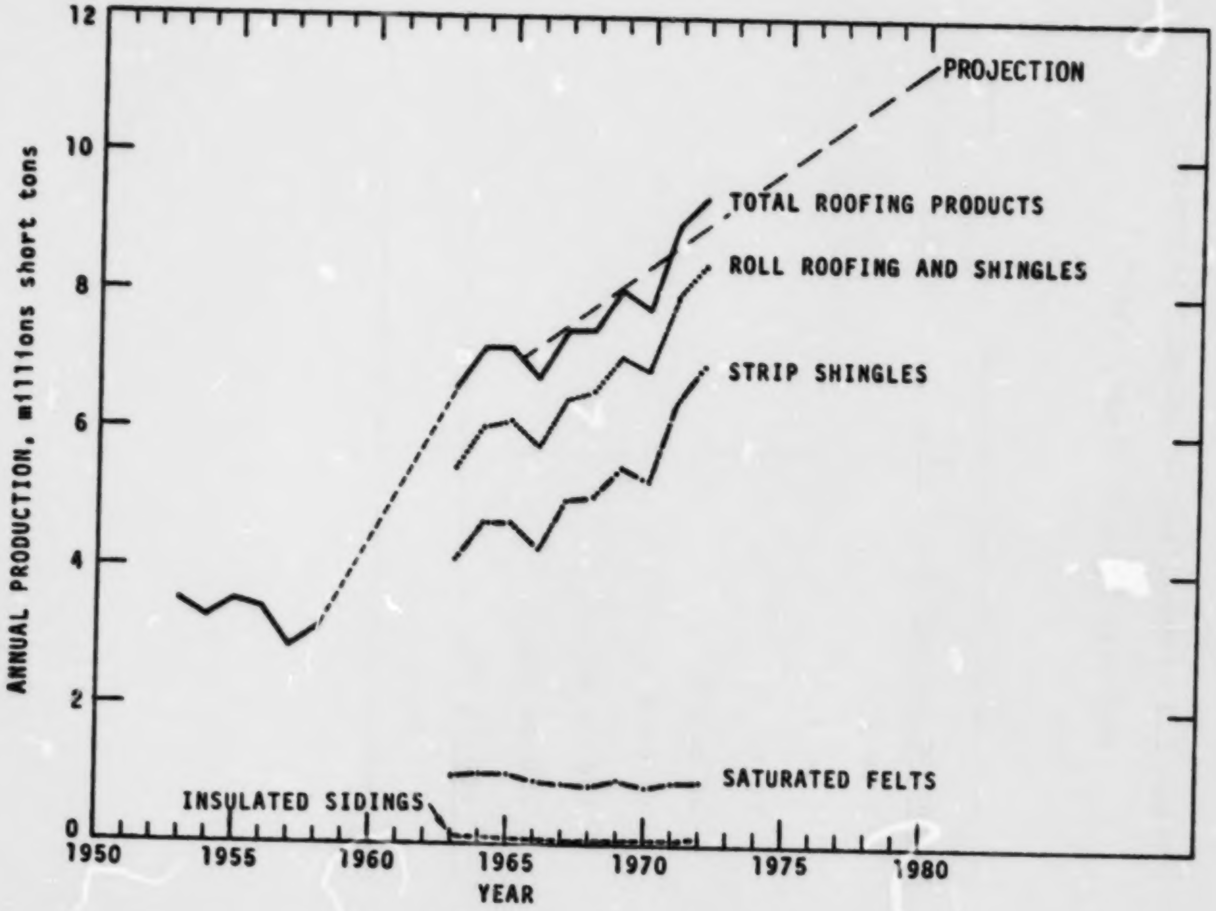


Figure 2.1 Sale of asphalt roofing products in the United States.

At this rate of increase, shipments of asphalt and tar roofing products should reach approximately 10 million short tons by 1977. This is approximately 600,000 short tons more than was shipped in 1972.

2.2.2 Relationship to Construction Industry

Roofing and sheet metal work are classified by the Bureau of Census as part of the construction industry. The Bureau of Census reports that the value of new construction in 1971 exceeded $109 billion.[2.4] Roofing and sheet metal contractors represented about 2.5 percent of the total construction industry receipts and 3.3 percent of the value of new construction in 1967.[2.5]

The correlation between new housing starts and the sale of asphalt roofing products, as shown in Figure 2.2, is not well defined. A better correlation is obtained by consideration of a single product such as strip shingles. Even in that case, however, the variations in new housing starts in the past decade do not always follow those in shingle production. On the other hand, trend lines for new housing starts and strip shingle production do exhibit similar growth patterns (about 5 percent per year).

2.2.3 Relationship to Mining and Mineral Products Industry

Several of the raw materials used in the manufacture of roofing products are classified by the Bureau of Census as Mining and Mineral Products. These are mainly petroleum asphalt, coal tar, and mineral fillers.

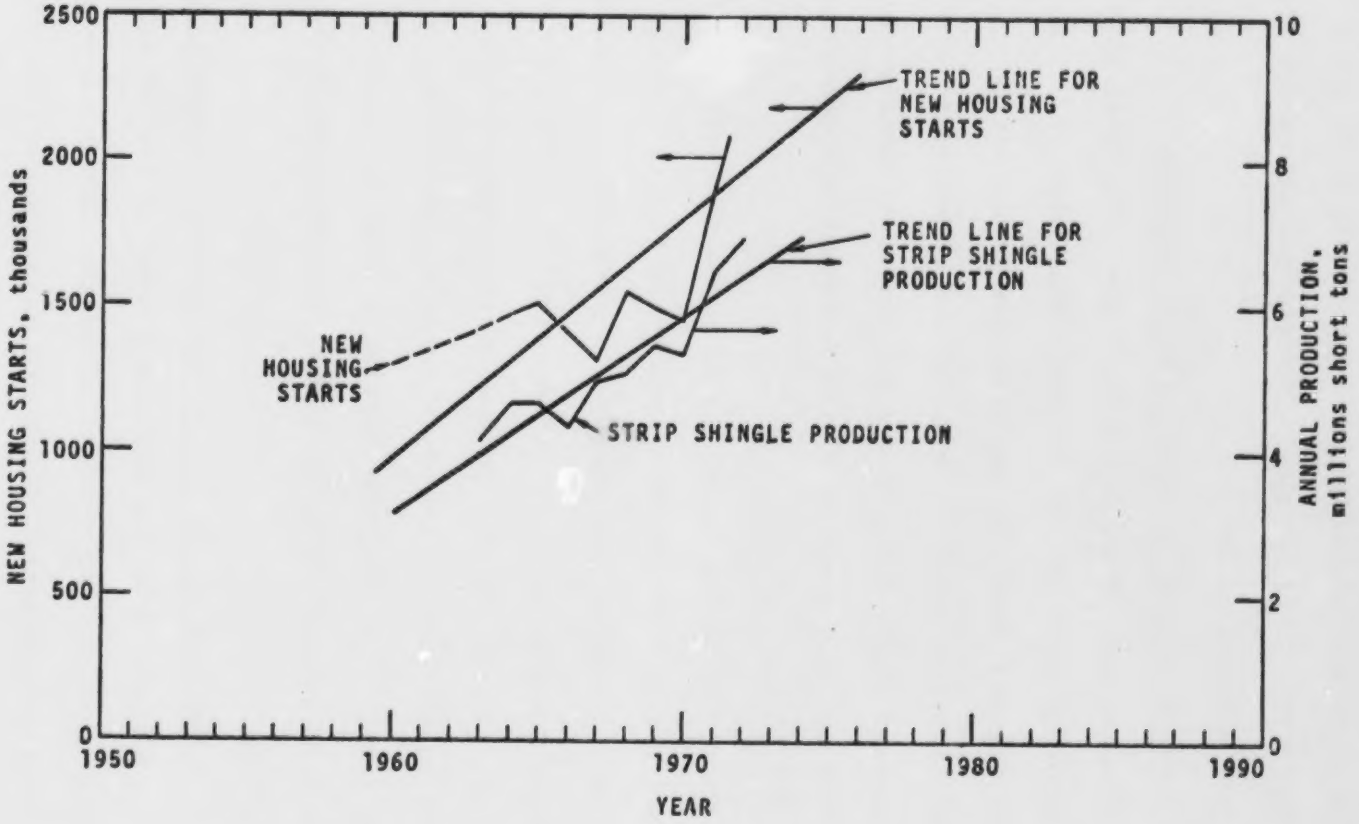


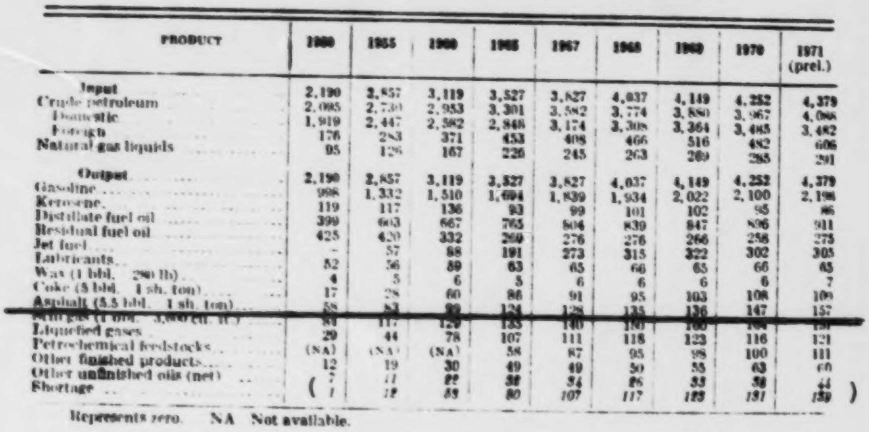
Figure 2.2 New housing starts and strip shingle production.

Figure 2.3 shows the amount of asphalt used in roofing products in relation to total asphalt production. These data show that the roofing products industry consumes approximately 16 percent of the asphalt produced. Paving consumes the major portion. The percent of asphalt used in the roofing industry has decreased from 25 percent in 1953 to the current 16 percent, even though total consumption has increased.

Table 2.3 shows the total asphalt produced as a function of quantities of petroleum and natural gas refined.

Table 2.3 PETROLEUM-RUNS TO STILLS AND REFINERY PRODUCTS, BY CLASS$^{2.6}$

(in millions of barrels of 42 gallons)



PRODUCT	1950	1955	1960	1965	1967	1968	1969	1970	1971 (prel.)
Input	2,190	2,857	3,119	3,527	3,827	4,037	4,149	4,252	4,379
Crude petroleum	2,095	2,730	2,953	3,301	3,582	3,774	3,880	3,967	4,088
Domestic	1,919	2,447	2,582	2,848	3,174	3,308	3,364	3,485	3,482
Foreign	176	283	371	453	408	466	516	482	606
Natural gas liquids	95	126	167	226	245	263	269	285	291
Output	2,190	2,857	3,119	3,527	3,827	4,037	4,149	4,252	4,379
Gasoline	998	1,332	1,510	1,694	1,839	1,934	2,022	2,100	2,196
Kerosene	119	117	136	93	99	101	102	95	86
Distillate fuel oil	399	663	667	765	804	839	847	896	911
Residual fuel oil	425	420	332	260	276	276	266	258	273
Jet fuel	–	57	88	191	273	315	322	302	305
Lubricants	52	56	89	63	65	66	65	66	65
Wax (1 bbl. = 280 lb)	4	5	6	5	6	6	6	6	7
Coke (5 bbl. = 1 sh. ton)	17	28	60	86	91	95	103	108	109
Asphalt (5.5 bbl. = 1 sh. ton)	58	83	99	124	128	135	136	147	157
Still gas (1 bbl. = 5,000 cu. ft.)	84	117	129	135	140	150	160	164	[illegible]
Liquefied gases	29	44	78	107	111	118	123	116	121
Petrochemical feedstocks	(NA)	(NA)	(NA)	58	87	95	98	100	111
Other finished products	12	19	30	49	49	50	55	63	60
Other unfinished oils (net)	*7*	*11*	*22*	*38*	*34*	*26*	*33*	*38*	*44*
Shortage	(*1*	*12*	*55*	*80*	*107*	*117*	*128*	*131*	*130*)

– Represents zero. NA Not available.

The quantity of asphalt produced as a percent of crude input increased from 2.6 in 1950 to 3.2 in 1960 and to 3.5 percent in 1972.

If asphalt shortages occur and prices rise, the roofing industry would probably increase its portion of total asphalt consumption and the paving industry would switch to other

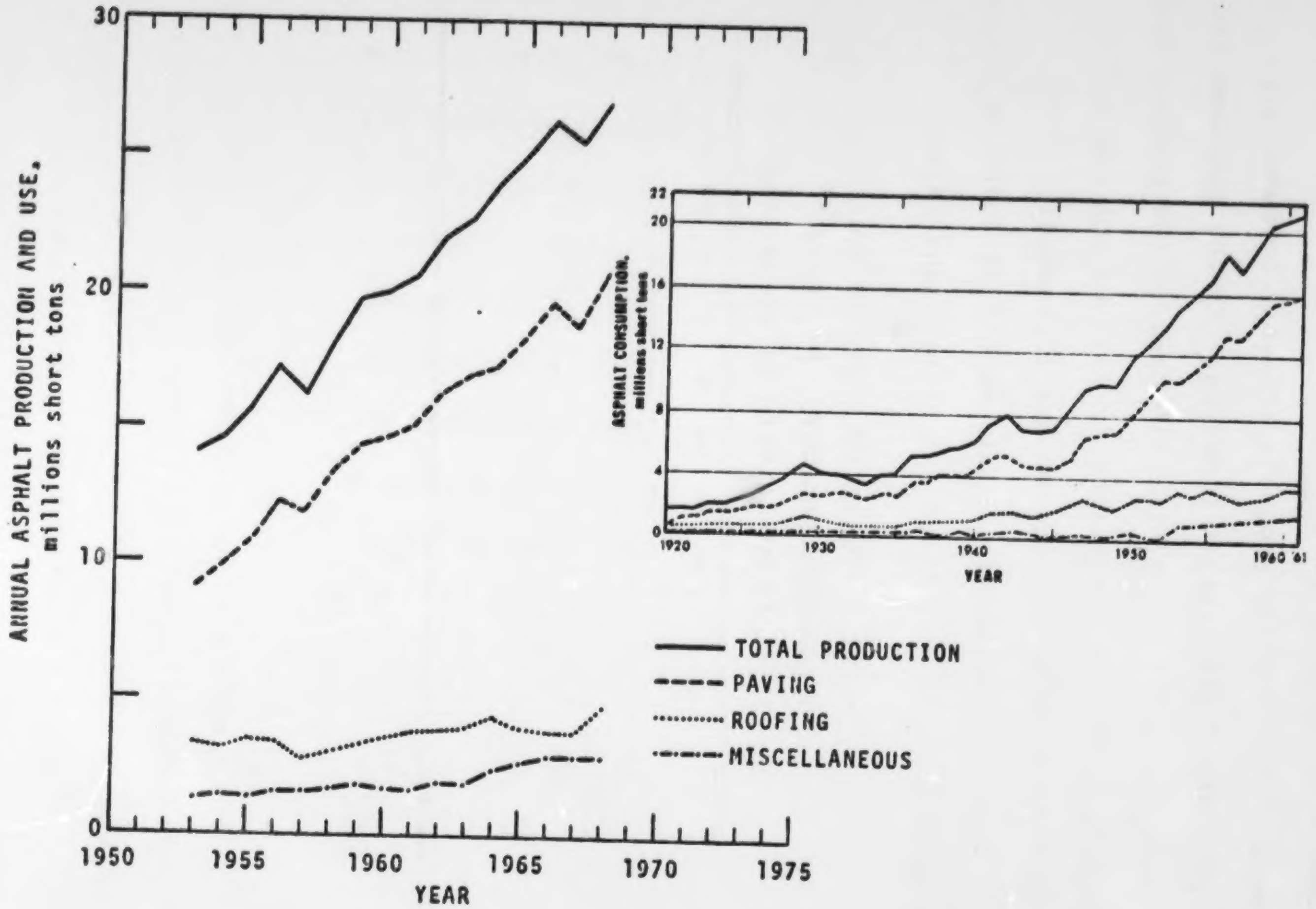


Figure 2.3 Production of petroleum asphalts in the United States.

paving materials, such as concrete. This would occur because there is no known substitute for asphalt roofing.

Although coal tars are a part of the mining and minerals industry classification, their use is not a major factor in the roofing industry because of their increased cost.

In 1972 the roofing industry used almost 2.5 million tons of mineral granules in shingle production. This amount, however, is less than 1 percent of total sand and gravel shipments in the U.S.

2.3 GEOGRAPHIC AND DEMOGRAPHIC DATA

Figure 2.4 shows the approximate location of asphalt producing centers in the U.S. and the number of identified establishments in each state. This map shows that major producing areas coincide with population centers and that this industry is located in 34 states. Table A-1, Appendix A, is a listing of individual asphalt roofing plants compiled from available listings. The table also gives the approximate dollar value of products produced in each state.

Six large plants account for about 20 percent of the production of asphalt roofing products in the United States. The balance of production is in medium-sized plants. Table 2.4 summarizes plant location and population data, which show that the large majority of plants are located in larger cities and urban areas.

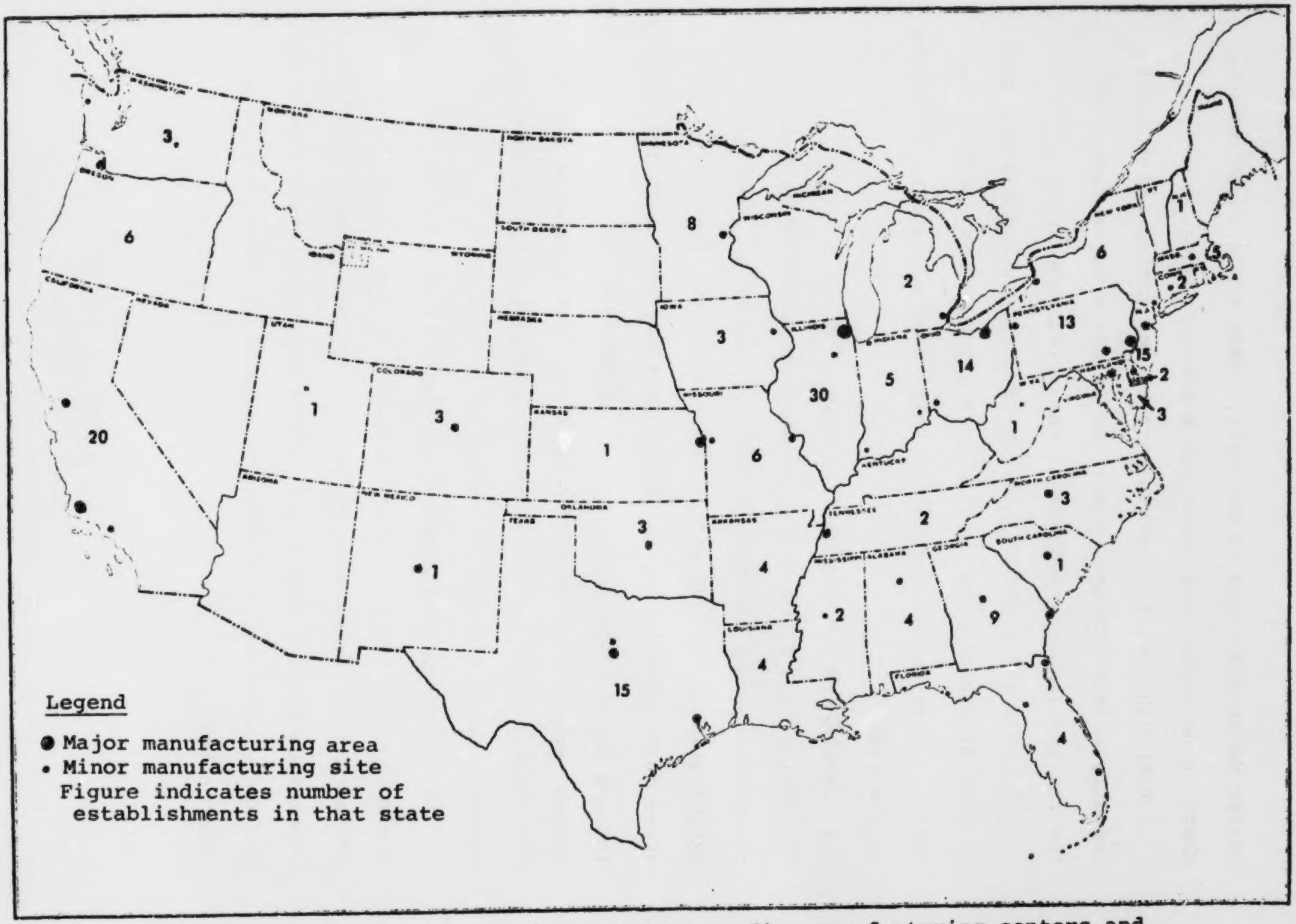

Legend
● Major manufacturing area
• Minor manufacturing site
Figure indicates number of establishments in that state
3
6
20
1
3
1
8
3
1
6
3
15
4
4
30
2
5
14
2
13
6
1
15
2
3
1
2
3
1
2
4
9
4
2
5
1

Figure 2.4 Location of major asphalt roofing manufacturing centers and number of plants identified in each state.

Reproduced from best available copy.

Table 2.4 POPULATIONS OF ASPHALT ROOFING PLANT AREAS

	Population of city, thousands					
	Under 10	10 to 50	50 to 100	100 to 500	500 to 1,000	Over 1,000
Number of plants	42	42	22	45	26	25
Six largest plants				1	2	3

Asphalt is a major component in roofing product manufacture as well as a by-product from crude oil refining. The quantity of asphalt present in the crude oil varies considerably from one geographic area to another. This variation would suggest that certain economies could be achieved by locating plants near the geographic areas where large quantities of crude oil are refined. This occurs to some extent, since a large portion of roofing product sales comes from plants located in Texas, California, Illinois, and Ohio, which also have large refining facilities. Location of plants in 30 other states, however, indicates that shipping economics favor manufacturing of roofing products in the geographical area in which they are to be used. To serve these regional plants, asphalt must be transported from the refinery to the plant.

2.4 ECONOMIC FACTORS

Table 2.5 shows the indices of wholesale prices on various commodities in selected years from 1950 to 1971.

Table 2.5 CONSTRUCTION MATERIALS INDICES OF WHOLESALE PRICES[2.5]

(1967 = 100)

COMMODITY	1955	1960	1965	1970	1971
All materials	90.4	95.5	96.8	112.5	119.5
Softwood lumber:					
Douglas fir	97.5	89.3	92.3	108.8	137.6
Southern pine	94.2	93.9	91.2	111.5	133.8
Other	100.6	95.3	95.4	115.1	145.3
Hardwood lumber	85.7	90.8	97.4	114.7	113.5
Millwork	87.7	93.1	96.0	116.0	120.7
Plywood	120.4	109.6	103.5	108.5	114.7
Softwood	143.4	113.2	105.7	113.6	127.2
Hardwood	100.2	105.2	100.5	102.9	100.7
Building paper and board	99.1	110.3	100.9	101.2	103.0
Prepared paint	82.1	92.1	96.4	112.4	115.6
Finished steel prod.:					
Structural shapes	71.0	93.4	96.2	115.3	126.8
Reinforcing bars	87.8	107.3	99.7	109.2	117.1
Black pipe, carbon	79.4	99.7	98.2	113.0	124.1
Wire nails	93.4	109.4	107.6	111.7	124.7
Nonferrous metal products	80.3	85.9	95.3	125.0	116.0
Copper water tubing	83.2	78.1	82.3	122.9	109.3
Building wire	64.7	61.7	82.5	123.0	97.9
Plumbing fixtures	88.7	93.3	93.3	112.5	116.4
Enameled iron	111.7	108.4	98.1	111.4	114.4
Vitreous china	102.1	106.3	96.5	108.9	111.8
Brass fittings	69.1	78.1	89.4	115.8	120.0
Heating equipment	102.5	105.8	98.9	110.6	115.5
Steam and hot water	86.3	99.8	99.4	110.7	116.4
Metal doors, sash, and trim	103.9	98.9	95.4	112.9	118.1
Plate glass	108.0	112.2	91.8	(NA)	(NA)
Concrete:					
Ingredients	85.2	97.0	97.5	114.6	121.9
Portland cement	85.0	100.3	98.1	115.7	124.6
Products	88.0	97.2	96.3	112.2	120.6
Pipe	87.6	101.9	94.0	103.5	112.0
Structural clay products	83.8	93.7	96.6	109.8	114.2
Gypsum products	90.9	99.1	101.2	100.0	106.8
Asphalt roofing	96.3	97.4	98.7	102.9	125.5
Insulation materials	113.7	110.9	97.2	123.1	131.7
Floor coverings:					
Asphalt tile	86.8	91.3	96.5	112.9	113.3
Vinyl covering	(X)	107.1	106.3	97.5	102.9

NA = Not available. X = Not applicable.

The indices for asphalt roofing generally appear very stable, showing a slight price increase over a long period of time. A large increase occurs, however, from 1970 to 1971; over 3 times the total rise for the last 15 years. Softwood lumber is the only other commodity that even approximates to such a pattern of sharp increase. With such a price jump not occurring throughout the industry, a drop in sales of asphalt products might be expected. The sales, however, increased. The following conclusions are drawn from these data on the relationship between the roofing industry and the total construction industry:

1) Although the roofing industry represents a major segment of the construction industry, the sale of roofing products

is not as dependent upon new construction starts as is the rest of the construction industry. This is true partly because of the large replacement market for roofing products.

2) After a tradition of few large price changes, the price of asphalt roofing increased 23.4 percent in 1 year with no apparent loss in sales, an indication that there are few economically feasible substitutes. This finding suggests that the industry could pass along price increases that might result from the installation of pollution control devices without substantial loss of product sales.

Currently, residential property holders spend about $320 per year per residence for improvements, maintenance, and repairs.[2.6] This amount has remained relatively constant since 1965 (when adjusted for inflation). Roofing represents about 7 percent of this maintenance bill, which includes roofing products, labor, and profits. Revenues of this segment of the construction industry exceeded $1 billion in 1971.

2.5 INDUSTRY GROWTH PROJECTIONS

The asphalt roofing industry appears economically healthy, having been able to date to pass on increased costs of raw materials and labor to the consumer. The industry has shown steady overall increases in sales, with fluctuations occurring at various intervals. Possible shortages of crude oil and therefore of asphalt, probably will not affect the roofing industry greatly, since it represents only a small portion of total asphalt consumption. Because the refining of crude always results in the production of asphaltic compounds or residua, changes in refining product mix will have little effect on asphalt production.

Records show that the production of saturated felts and insulated siding has been fairly level. Production of roofing products (especially shingles), however, has grown at an average rate of about 4.6 percent during the last 10 years.

Table 2.6 shows the percentage changes in various parameters and changes in roofing product sales. No direct correlations between these parameters are evident.

Projections of the growth trends of the asphalt roofing industry are thus best based on past performance, as shown earlier in Figure 2.1; the industry will probably continue for the near future to grow at an average rate of 3 to 4 percent per year. This trend will continue until some other product finally replaces asphalt as an economical roofing constituent. No such product is currently evident.

Table 2.6 ANNUAL CHANGES IN SALES OF ASPHALT ROOFING PRODUCTS AND OTHER PARAMETERS

(percent)

Years	Change in roofing product sales	Change in population [a]	Change in sales of petroleum asphalts for roofing products [b]	Change in value of new construction [c]	Change in new housing starts [d]
53-54		+1.8	-6.0	+5.7	+7.9
54-55		+1.8	+7.8	+12.4	+6.1
55-56		+1.8	-2.6	+2.3	-18.0
56-57		+1.8	-17.3	+3.2	-9.2
57-58		+1.7	+10.0	+2.1	+12.9
58-59		+1.7	+6.4	+10.3	+12.4
59-60		+1.6	+6.9	-1.2	+19.8
60-61		+1.6	+3.1	+3.0	+5.3
61-62		+1.5	+5.7	+6.5	+9.3
62-63		+1.5	-0.5	+7.7	+10.1
63-64	8.9	+1.4	+10.4	+4.4	-4.9
64-65	0.5	+1.2	-4.4	+8.9	-3.3
65-66	-6.0	+1.1	-1.0	+3.5	-20.8
66-67	10.2	+1.1	-0.6	+2.0	+10.5
67-68	0.7	+1.0	+20.0	+11.7	+16.9
68-69	7.4	+1.0	-14.4	+7.8	-2.9
69-70	-3.0	+1.0	+4.1	-0.7	-2.0
70-71	14.7	+1.0	+4.1	+16.3	+4.2

[a] U.S. Bureau of Census, Current Population Report Series, P-25, Nos. 465 and 482.

[b] American Petroleum Institute, Petroleum Facts and Figures, 1971 Edition.

[c] Economic Statistics Bureau of Washington, D.C. Handbook of Basic Economic Statistics (1973) Vol. XXVII #1

[d] Ibid

3.0 RAW MATERIALS AND PRODUCT SPECIFICATIONS

This section describes the raw materials used in the asphalt industry and the resulting asphalt products as a basis for understanding of the major process steps and potential pollutant emissions. Additional detailed information is given in the references for this section.

3.1 RAW MATERIALS

Three major types of raw materials are required to produce asphalt roofing materials: (1) bitumens, consisting mainly of asphalt and tar, (2) solid filler and coating materials, and (3) felts and woven fabrics.

3.1.1 Bitumens

Within the United States the term "bitumen" refers to either asphalt or coal tar products. The two major sources of bituminous material are petroleum, which yields petroleum asphalt, and coal, which yields coal tar and roofing pitch.[3.1] Table 3.1 classifies bituminous materials.

3.1.1.1 Asphalt - Asphalt is defined by the American Society for Testing and Materials as "a dark brown to black cementitious material, solid or semisolid in consistency, in which the predominant constituents are bitumens which occur in nature as such or are obtained as residua in refining petroleum."[3.3]

Table 3.1 CLASSIFICATION[a] OF BITUMENS[3.2]

Asphalts

1. Petroleum asphalts
    - A. Straight-reduced asphalts
        1. Atmospheric or vacuum reduction
        2. Solvent precipitated
    - B. Thermal asphalts, as residues from cracking operations on petroleum stocks
    - C. Air-blown asphalts
        1. Straight-blown
        2. "Catalytic"-blown
2. Native asphalts
    - A. With mineral content below 5 percent
        1. Asphalitites such as gilsonite, grahamite, and glance pitch
        2. Bermudez and other natural deposits
    - B. With mineral content over 5 percent
        1. Rock asphalts
        2. Trinidad and other natural deposits

Tars and derivatives

1. Residua from coke-derived coal tars
    - A. Coal tars reduced to float grades, as road tar grades for paving purposes
    - B. Coal-tar pitches, with reduction carried out to soften-point grades
2. Residua from other pyrogenous distillates as from water-gas, wood, peat, bone, shale, rosin, and fatty acid tars

---

[a] The following terms relate to the generic terms used in defining asphalt composition:

Carboids - highest carbon fraction insoluble in CS_2.
Carbenes - insoluble in CCL_4 but soluble in CS_2.
Asphaltenes - insoluble in pentane, hexane, and naptha.
Petrolenes (malthene) - define as nonasphaltenes.
Carbines are not present in blown asphalts.

Petroleum asphalts are by far the most important source of asphalt in the United States today. These asphalts result from the distillation of crude oil and represent the non-volatile components remaining in the still after distillation (bottoms). These asphalts are mainly classified by their physical characteristics, not their chemical composition.

Most asphalt stock (flux) used in the roofing industry is air-blown to modify the properties of the flux. Asphalt must have very high viscosity (estimated at 7 x 10^8 poises minimum) to hold granules in place in roofing shingles. Granule movement during the life of the shingle must be small. Air-blown asphalts have higher viscosity than other types and are therefore more suitable for shingle manufacture.

Because of their cohesiveness, asphalts also are inherently waterproof and weather resistant. Air-blown asphalts are particularly durable. Table 3.2 shows the chemical analyses and some physical properties of typical asphalts. The relatively high softening point of air-blown asphalt results from the removal of some of the more volatile compounds.

Table 3.2 ELEMENTAL ANALYSES OF ASPHALT FRACTIONS AND NATURAL ASPHALTS[3.3]

Petroleum asphalts	Number of asphalts	Percent by wt. of asphalt	Softening point (ring and ball), °F	Elemental analyses, % by wt				
				C	H	S	N	O[a]
Residual	4		135-165					
asphaltenes		23.0-30.6		80.5-83.5	7.3-8.0	4.6-8.3	0.4-0.9	0-1.8
petrolenes		69.4-77.0		82.0-84.8	10.0-10.6	0.4-5.5	0.5-0.5	0.7-1.4
Air-blown	4		180-194					
asphaltenes		31.7-39.5		80.7-84.8	7.8-8.2	3.7-7.3	0.5-0.8	2.0-2.8
petrolenes		60.5-68.3		82.5-84.3	10.9-11.5	2.3-5.4	0.4	0.8-1.3
High cracked	1		124					
asphaltenes		24.1		88.9	5.9	3.0	0.4	
petrolenes		75.9		87.9	7.9	3.7	0.5	
Natural asphalts								
Trinidad	typical		200-207	82.3	10.7	6.2	0.8	
Bermudez	typical		145-160	82.9	10.8	5.9	0.8	

[a] Oxygen determined by difference.

3.1.1.2 Tars - Tars constitute the volatile oily decomposition products obtained in the pyrogenous treatment of organic substances. The most important source of coal tar in the United States is from coke oven operations.

The use of coal tar and coal-tar pitch in the roofing industry has been almost exclusively confined to built-up roofing, i.e. tar applied directly to the roof. These tars represent only a small portion of the total roofing industry materials.

3.1.2 Fillers

Fillers used for roofing products include mineral fillers such as sand and other fine oxides, silicates, carbonates, and sulfates; organic fillers such as vegetable starches, grain dust, coal, and peat; inorganic fibers such as glass and asbestos; and organic fibers such as wood, rag, and paper. These fillers impart various physical properties and decorative variations to roofing products.[3.4]

3.1.3 Felts and Woven Fabrics

Felts are generally formed of paper, rag, or asbestos fibers, with or without additions, on a machine similar to that used for manufacturing paper. Felts are marketed on the basis of weight in pounds per 480 square feet, known as the "number" ranging from 15 to as high as 90. Most common weights are in the 27 to 55 pound range. The "number" of the felt multiplied by 0.225 will give its weight in pounds per 108 square feet (100 ft^2 of coverage). High-grade rag felt will test approximately 1 mil in thickness, and not less than 0.5 pound on the Mullen strength tester per unit "number". These relations hold approximately constant for all weights. The use of a perforated sheet of felt has been suggested to provide a change in weight.[3.5]

Woven fabrics ordinarily used for manufacturing prepared roofings include burlap or hessian (composed of jute fibers), sheeting, and osnaburg and duck (composed of cotton fibers). These are marketed in various weights, expressed in arbitrary ways. Woven fabrics do not take up nearly so large a percentage of bituminous saturation as felted fabrics.[3.5]

3.2 PRODUCT DESCRIPTION

3.2.1 Prepared Roofing

Prepared roofings are comprised of a single layer or multiple layers of a fabric (woven or felted), saturated, and/or coated with bituminous compositions. The finished product is supplied in flat sheets or wound in rolls. The fabrics and bituminous compositions can be assembled in an extremely large number of combinations.

Laminated roofing consists of two or more layers of bituminized felted or woven fabrics, in various combinations with structural supports (wire mesh, sheet metal, etc.). Roll roofing can also be decorated with granular materials or cut to special shingles.

3.2.2 Asphalt Shingles

Asphalt shingles are cut in relatively small units from roofing coated with mineral granules and are intended to be laid in overlapping courses. Prepared roofing shingles are cut in a variety of patterns and finishes.

"Individual shingles" are units cut in a single pattern in distinction to the "strip shingles," which are cut with a repetition of pattern.

3.2.3 Adhesive Compounds for Built-Up Roofs, Dampproofing, and Waterproofing

Adhesive compounds are used in three classes of work:

1. Construction of built-up roofs exposed to wide temperature fluctuations.
2. Construction of above-ground membrane waterproofing of structures exposed to wide temperature fluctuations and severe vibrations (i.e., bridges, culverts).
3. Construction of underground membrane waterproofing exposed to moderate temperature conditions (i.e., tunnels, foundations, dams).

The adhesive products are made of tar-pitches and asphalts similar in composition to the surface coatings of sheet roofings. Adhesive compounds for built-up roofing are generally of softer consistency than the coating compounds for prepared roofing, but are of similar composition.

3.2.4 Bituminous Cements

Bituminous cements are of plastic, troweling consistency and are used for repairing composition or metal roofing, above-ground dampproofing, and to a small extent, waterproofing. Often these products are referred to as "asphalt putty." Cements may consist of two or more of the following materials:[3.6]

1. A base of one or more bituminous materials, with or without the addition of vegetable oils and resins.

2. Mineral fillers such as those used for filling the coatings of prepared roofings (clay, cement, influsorial earth, calcium carbonate, mica, soapstone) and pigments.

3.3 NEW PRODUCT DEVELOPMENT

Research is under way on producing roofing tiles and other roofing accessories from molded mixtures of asphalt and other fibrous and mineral matter.[3.7] Several unsuccessful attempts have been made to produce such products commercially.

The process generally involves mastication and subsequent molding under pressure. Mineral fillers with dispersed asphalt can be formed into sheets, coated, surfaced, and cut into any desired form of roofing product.

Production of roofing materials by extruding a mastic of asphalt, mineral filler, and glass fibers in sheet form, coated with asphalt and surfaced with granules, has been proposed. This product could be reinforced with a variety of items (bituminized felt, metal, or wooden lathes) and the surface glazed with fusible glass. Molded units have also been proposed for roof copings and interlocking roof tiles.

4.0 PROCESS DESCRIPTION AND ATMOSPHERIC EMISSIONS

4.1 GENERAL

Figure 4.1 is a simplified schematic diagram of the asphalt roofing manufacturing process. Saturated felt is usually coated on both sides with an asphalt coating of controlled thickness. In production of shingles, colored granules are embedded firmly in the surface coating on one side; a parting agent is applied to the other side; and the felt is cut into shingles or rolled on a mandrel. The purpose of the parting agent is to prevent the shingles or felt surfaces from sticking together. When roofing is made in rolls, no granules are used. The asphalt used in the saturator is first prepared by blowing air through the raw asphalt to achieve selected properties.

The main points of emission of organic particulate in the roofing process are the saturator, the blowing operation and the hot asphalt storage tanks. The air-blowing operation is not always done at the plant site, and the asphalt is frequently purchased in the blown form. The sand dryer and application of the mineral parting agent are potential sources of inorganic particulate. The coating mixer, where the asphalt sand is blended prior to application, is a minor source of particulate emissions.

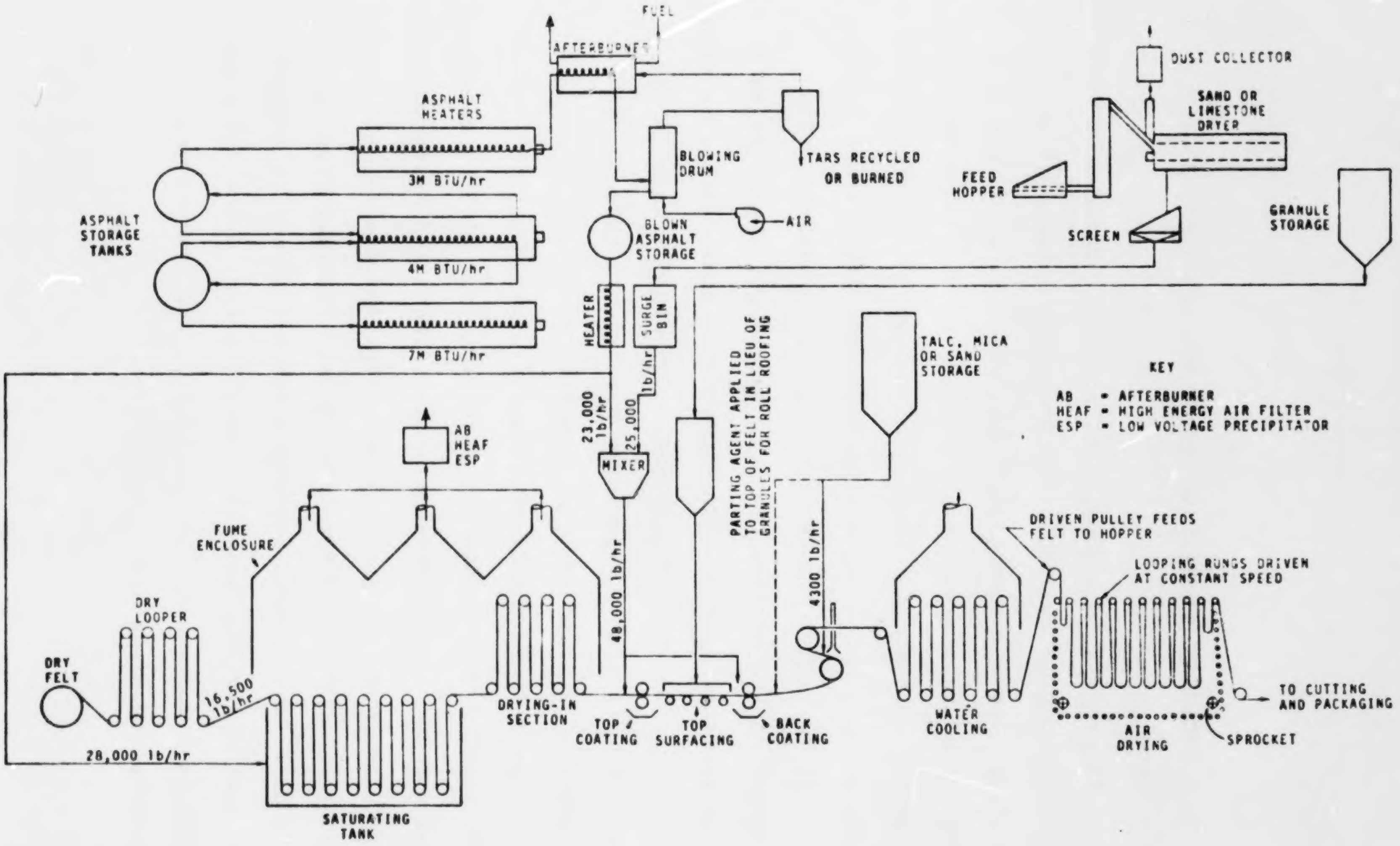

FUEL
AFTERBURNER
ASPHALT HEATERS
3M BTU/hr
4M BTU/hr
7M BTU/hr
ASPHALT STORAGE TANKS
BLOWING DRUM
TARS RECYCLED OR BURNED
AIR
BLOWN ASPHALT STORAGE
HEATER
SURGE BIN
DUST COLLECTOR
SAND OR LIMESTONE DRYER
FEED HOPPER
SCREEN
GRANULE STORAGE
23,000 lb/hr
25,000 lb/hr
MIXER
48,000 lb/hr
PARTING AGENT APPLIED TO TOP OF FELT IN LIEU OF GRANULES FOR ROLL ROOFING
TALC, MICA OR SAND STORAGE
4300 lb/hr
KEY
AB = AFTERBURNER
HEAF = HIGH ENERGY AIR FILTER
ESP = LOW VOLTAGE PRECIPITATOR
AB
HEAF
ESP
FUME ENCLOSURE
DRY FELT
DRY LOOPER
16,500 lb/hr
28,000 lb/hr
SATURATING TANK
DRYING-IN SECTION
TOP COATING
TOP SURFACING
BACK COATING
WATER COOLING
DRIVEN PULLEY FEEDS FELT TO HOPPER
LOOPING RUNGS DRIVEN AT CONSTANT SPEED
AIR DRYING
SPROCKET
TO CUTTING AND PACKAGING

Figure 4.1 Asphalt roofing mill process.flowsheet.

4.2 SATURATOR

4.2.1 Process Description

Saturation is accomplished by dipping the felt in asphalt, spraying it with asphalt, or both. In these operations the asphalt is maintained at a temperature of 400 to 500°F. Where both methods are used, the felt is sprayed before dipping. This spray, applied to one side of the felt only, drives the moisture out of the opposite side. The felts should contain less than 7 percent moisture to prevent subsequent blistering of the asphalt. The trend has been away from spraying and presaturation, since moisture can also be boiled out of the felt during submersion in the hot liquid asphalt. In any case, the spray and dipping operations are generally housed together and form one process.

Standard felt weights (thickness) are 15, 30, and 55 pounds per 480 square feet of felt material. The felts are a fibrous paper similar to thin cardboard, as described in Section 3.0.

As shown in Figure 4.1, a saturator line consists of a large roll of felt (actually paper), a dry looper section that takes up surges in line speed, a spray section (if used), a dipping section, a drying section with heated rolls, coating and surfacing areas, a final cooling section consisting of both water sprays and water-cooled rolls, a finish looper area, and finally a roll winder or shingle cutter. Typical lines are about 5 to 6 feet wide for processing a 4- to 5-foot width of felt, and they are over 100 feet long.

The saturation process is limited by the properties of the felt and the speed at which the felt can be fed to the saturator. Maximum speeds are 600 feet per minute (fpm) for 15- to 30-pound felts and 400 to 500 fpm for the heavier weights; more typically, however, the average speeds are 250 to 400 fpm. Although mechanical breakdowns and changes of the felt roll cause shutdown of the line, the process is essentially continuous, often over more than one shift per day and for 6 or 7 days per week.

The entire saturator is enclosed by a hood, which vents the fumes to a control device or directly to the atmosphere. These hoods have a wide range of capture efficiencies, depending on design and ventilation rates. The impact of OSHA regulations has effected some improvements in hood capture efficiencies; some saturator rooms, however, are characterized by a hazy atmosphere.

4.2.2 Atmospheric Emissions From Saturators

Emissions from the saturator consist of water vapor, condensed asphalt (hydrocarbon) droplets, and gaseous organic vapors. These emissions are highly visible and odorous. There are no available published test results relating emissions to process production rates.

4.2.2.1 Particulate - Particulate emission rates depend on a number of factors including weight and moisture content of the felt, line speed, and the spraying/dipping process. Spraying probably tends to increase emissions by direct entrainment of asphalt in the vent air stream. Most felts are dipped. Weight and moisture content of the felt and line speed determine the total amount of water entering the saturator and also the total process weight. Moisture in the felt is vaporized by the hot asphalt, and the vapor carries with it small asphalt droplets and gaseous products steam-distilled from the asphalt.

Emission data from the literature and from vendors are summarized in Table 4.1. These data show particulate emissions in the range of 19 to 71 pounds per hour; the test results did not include process weight data.

Table 4.1 REPORTED UNCONTROLLED PARTICULATE EMISSIONS FROM ASPHALT SATURATORS

scfm[a]	Temperature, °F	Grains/scf	lb/hr	Reference
20,000	140	0.42	71	4.1
12,500	130	0.59	63	4.1
10,100	260	0.79	68	4.1
12,000	138	0.53	55	4.1
27,300[b]	128-134	0.08-0.10[b]	19-24[b]	4.2

[a] Standard cubic feet per minute corrected to 60°F and 14.7 psia.

[b] In-stack filterable particulate only; other data include condensable particulate.

Particulate emission data obtained during the field tests conducted as part of this study are presented in Table 4.2. The particulate sampling techniques, as described in Appendix B, followed methods 1 through 5 of the Federal Register of

Table 4.2 ASPHALT SATURATOR - PARTICULATE EMISSION DATA

	Felt		Process rates, ton/hr		Vent gas[b]			Uncontrolled particulate				Controlled particulate			
	Weight,[a] lb	Moist., %	Felt	Product[e]	Flow,[c] MSCFM	Temp., °F	Moist., %	gr /DSCF[d]	lb/hr	lb/ton		gr/DSCF	lb/hr	lb/ton	
										felt	product[e]			felt	product
Plant A	55	3.2	5.75	16.0	30.0	165	1.5	0.28	69	12	4.3	0.068	17.8	3.1	1.2
								0.32	82	14	5.1	0.080	21.3	3.8	1.3
								0.14	35	6	2.2	0.067	15.3	2.7	1.0
	27	3.5	1.8	4.4	33.5	137	1.1	0.23	67	36	14.8	0.021	5.2	3.0	1.2
								0.12	35	19	7.8	0.016	4.1	2.3	1.0
								0.05	15	8.5	3.5	0.022	5.6	3.1	1.3
Plant B	55	6.5	5.4	14.2	10.8	141	3.8	0.30	27	5.0	1.9	0.12	17.7	3.3	1.2
	55	6.5	6.1	16.2	8.3	153	3.5	0.47	34	5.5	2.1	0.08	9.3	1.5	0.6
	27	7	1.3	3.2	9.9	187	1.4	0.45	33	25	10	0.12	16.4	12.6	5.1
	27	7	1.7	4.3	10.8	198	1.6	0.34	32	19	7.4	0.10	14.6	8.6	3.4

[a] pounds per 480 square feet of felt
[b] at inlet to control device
[c] 1000 of cubic feet per minute corrected to 70°F and 29.92 in. Hg, dry basis.
[d] Grains per dry standard cubic foot
[e] Product is the saturated felt. Saturant used is approximately 1.6 times felt weight.

Note: Plant A was equipped with a HEAF

Plant B was equipped with an afterburner

gr/DSCF X 2288 = milligrams/cubic meter

lb/ton X 0.499 = kilograms/metric ton

December 23, 1971. The particulate train was, however, modified by placing the filter after the impingers to collect condensible compounds. Tests were conducted at two plants during processing of two different weights of felt at each plant. The 55-pound felts were 4 feet wide and ran at line speeds of approximately 413 fpm at plant A, and from 277 to 317 fpm at plant B. In all cases the asphalt impregnated on the felt amounted to approximately 1.6 times the weight of the felt. The 27-pound felt was 3 feet wide and ran at line speeds of 360 fpm at plant A, and 250 to 340 fpm at plant B. Moisture contents of the felt at plant B were approximately twice those at plant A. Asphalt was maintained at a temperature of 430°F at plant A and 450°F at plant B.

The data in Table 4.2 show that uncontrolled emissions at plant A were highly variable. Average hourly emissions were 62 pounds for the 55-pound felt and 39 pounds for the 27-pound felt, yielding averages of 3.9 and 8.7 pounds per ton of saturated felt for the two weighted tested. Emissions from the saturator were controlled by a HEAF® system (see Section 5.0) at plant A. With the larger machine, the HEAF operated at a pressure drop of 27 inches of water; with the smaller machine the observed pressure drop was 20.5 inches. Tests at this plant were not performed simultaneously at the control device inlet and outlet, since no sampling sites were available at

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the inlet. Instead, samples of uncontrolled emissions were obtained while the control device was bypassed. Controlled and uncontrolled emissions are thus not directly comparable, but average values can be compared, since the same product was being run. Values obtained at the outlet indicated average hourly emission rates of 18 and 5 pounds for the 55- and 27-pound felts, respectively. Comparable control device efficiencies were 71 percent and 87 percent by weight. These emissions averaged 1.2 pounds per ton of saturated felt for both weights of felt.

The fairly low collection efficiencies for this control device, which relies mainly on mechanical impaction, are probably due to the large amount of condensible matter that passes through the HEAF in gaseous form and to the fine particle size of the particulate matter. Some HEAF units, however, have demonstrated measured efficiencies above 98 percent as applied to asphalt saturators. Differences in sampling procedures could account for differences in emission rates and collection efficiencies.

At plant B the two weights of felt were run on the same line at different times. Uncontrolled emissions from plant B ranged from 27 to 34 pounds per hour and were essentially the same for both felt weights. This apparent anomaly is due to mechanical problems with the 55-pound felt machine, requiring frequent opening of the hood doors with loss of fume into the room and thus lower measured emissions from the stack. The machine that ran the 27-pound felt operated much more consistently with the hood tightly closed; the 32.5 pound-per-hour emission rate is representative of emissions from this line. The average emission rate of 8.7 pounds per ton of product is identical to the average obtained with the 27-pound felt at plant A.

The plant B saturator was controlled with a fume incineration system, in which the exhaust fumes were passed into a process heater furnace fired with No. 2 fuel oil. The process heater was used to heat the saturant in the saturation process. The heater was regulated by the saturant temperature, automatically reducing the firebox temperature when the saturant became too hot. Maximum heat input of the furnace was 10 million BTU per hour. The variable operation of the fume incinerator and the burning of No. 2 fuel oil caused low particulate collection efficiency. Controlled emissions were 13.5 and 15.5 pounds per hour for the 55- and 27-pound felts, respectively, (0.9 and 4.2 pounds per ton of product) resulting in collection efficiencies of 56 and 52.3 percent by weight.

Particle size data on saturator emissions are lacking. Samples obtained during the field testing portion of this study with a Brink's Impactor yielded the data shown in Figure 4.2. These limited data show that the particles emitted are very small, 50 percent measuring less than 0.8 micron in diameter. This small particle size is evidenced by the high opacity of the plume when it is not controlled.

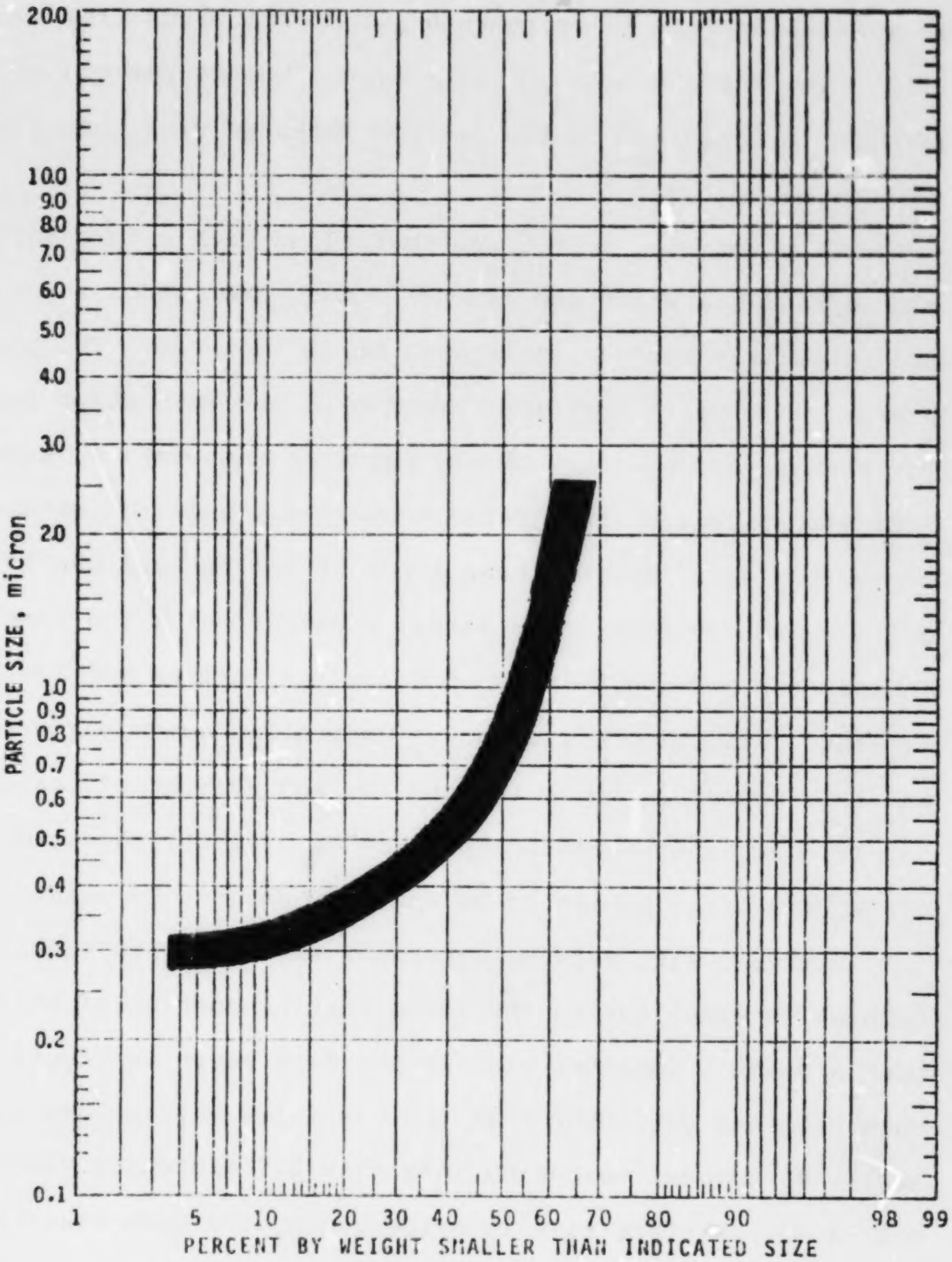

Figure 4.2 Particle size distribution in uncontrolled saturator exhaust.

4.2.2.2 PPOM Emissions - Table 4.3 summarizes the PPOM emissions measured in this study. These data were obtained by using the EPA-5 particulate sampling method with filter relocated to follow the impinger as described in Appendix B. The collected sample fractions were extracted with methylene chloride. The remaining sample was separated on a chromatographic column and analyzed by mass spectrometry. These data show uncontrolled total PPOM emissions of 21 to 114 milligrams (mgm) per hour at plant A (0.00012 percent to 0.00048 percent of total particulate matter), the heavier shingle material yielding the higher emission rate. At this plant the PPOM emissions were reduced by passage of effluent through a HEAF unit, the emissions measuring 5.0 and 37.6 mgm per hour (0.0002 to 0.00044 percent of total particulate emissions). Emission rates for each of the individual PPOM compounds were lower after passage through the HEAF unit, and overall collection efficiency was 70 percent.

At plant B, the uncontrolled PPOM emissions ranged from 16.6 to 27 mgm per hour (0.00012 to 0.00018 percent of total particulate). These emissions were controlled by a fume incinerator. This device, however, had essentially no effect on the PPOM compounds; emissions at the inlet and the outlet, measured simultaneously, were approximately the same.* Since total particulate was reduced, the portion of PPOM as a percent of particulate increased to 0.0003 percent.

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*Neglecting the unusually high benz(a)pyrene and benz(e)pyrene values, which were apparently caused by interferences in analyses.

Table 4.3 PPOM EMISSIONS FROM ASPHALT SATURATORS

Compound	Uncontrolled								Controlled							
	Plant A Shingle		Plant A Roll		Plant B Shingle		Plant B Roll		Plant A Shingle		Plant A Roll		Plant B Shingle		Plant B Roll	
	μgm/m³	mgm/hr	μg/m³	mgm/hr	μgm/m³	mgm/hr	μgm/m³	mgm/hr	μgm/m³	mgm/hr	μgm/m³	mgm/hr	μgm/m³	mgm/hr	μgm/m³	mgm/hr
Benz(c)phenanthrene	0.50	25.0	0.07	5.40	0.34	5.90	0.03	13.0	0.33	17.0	0.03	0.91	0.40	13.0	0.32	9.00
7,12-Dimethylbenz (a)anthracene	0.35	10.0	0.03	2.30	0.34	5.90	0.07	14.0	0.10	4.50	0.02	0.91	0.12	3.30	0.19	5.00
Benz(e)pyrene	0.34	10.0	0.02	1.00	0.16ª	2.00ª	--ª	--ª	0.25	12.0	0.01	0.45	0.04ª	1.10ª	4.20ª	130.0ª
Benz(a)pyrene	0.25	13.0	0.09	7.30			--	--	0.05	2.30	0.04	1.00				
3-Methylcholanthrene	0.38	20.0	0.05	4.10	--	--	--	--	--	--	0.02	0.91	--	--	--	--
Dibenz(a,h)pyrene	0.19	10.0	--	--	0.06	1.00	--	--	0.03	0.91	--	--	0.01	0.27	0.16	4.90
Dibenz(a,i)pyrene	0.19	10.0	--	--	0.06	1.0	--	--	--	0.91	--	--	0.01	0.27	0.16	4.90
Total		114.0		21.0		16.6		27.0		37.6		5.0		17.9		190.4

ª Benz(a)pyrene + Benz(e)pyrene total. The gas chromatograph quantitation of benz(a)pyrene and benz(e)pyrene was hampered by interferring peaks.

-- Signifies non-detectable.

Note: Plant A utilized HEAF control device.
Plant B utilized afterburner

PPOM compounds thus amount to approximately 0.0003 percent of the total particulate in either controlled or uncontrolled emissions. Table 4.4 summarizes the PPOM emissions measured in this study with relation to total particulate and product tonnages.

Table 4.4 RELATION OF PPOM TO TOTAL PARTICULATE AND PRODUCT TONNAGES

	Uncontrolled		Controlled	
Felt weight	% PPOM x 10^{-4} in particulate	mg/ton of product	% PPOM x 10^{-4} in particulate	mg/ton of product
55	1.2-4.8	2-8	2.8-4.4	1.5-2.4
27	1.2-1.8	5-7	2.0-3.3	1.1-6.3

4.2.2.3 Gaseous Emissions - Although reported data for gaseous emissions from the saturator are practically nonexistent, gaseous hydrocarbons, carbon oxides, aldehydes, and odorous compounds are emitted because of the nature of the process.

Table 4.5 summarizes the gaseous emission data obtained during the field tests of two saturators. The saturator exhaust is essentially air at a temperature of 140 to 190°F, containing 1.1 to 3.8 percent moisture. In all cases, multiple samples of each contaminant were taken during the particulate tests. Hydrocarbons and carbon monoxide (after conversion to methane) were analyzed with a flame ionization detector. Aldehydes were collected in a solution of MBTH (3-methyl-2-benzothiazolone hydrazone hydrochloride and analyzed colorimetrically.

Table 4.5 GASEOUS EMISSIONS FROM ASPHALT SATURATORS

	EMISSIONS	Uncontrolled			Controlled		
		ppm[a]	lb/hr	lb/ton	ppm[a]	lb/hr	lb/ton
Plant A	CO[a]						
	Range	512 - 614			410 - 466		
	Average	563	81.7	5.1	438	56.6	3.5
	HC[b]						
	Range	43 - 58			71 - 79		
	Average	51	4.2	0.26	75	5.5	0.34
	Aldehydes[c]						
	Range	2.39 - 4.80			0.69 - 2.5		
	Average	3.35	0.52	0.033	1.96	0.27	0.017
Plant B	CO						
	Range	2.3 - 192			0 - 70		
	Average	50.4	2.2	0.14	36.2	2.5	0.16
	HC[b]						
	Range	180 - 970			0 - 360		
	Average	520	12.8	0.84	246	9.7	0.64

[a] Parts per million by volume.
[b] Total gaseous hydrocarbons expressed as methane.
[c] Total aldehydes expressed as formaldehyde (CHOH).

Measurements for gaseous hydrocarbons, aldehydes, and carbon monoxide were made at plant A. These measurements showed average carbon monoxide emissions in the range of 57 to 82 pounds per hour (3.5 to 5.1 pounds per ton of saturated felt), at concentrations of 410 to 614 ppm. Concentrations after the HEAF unit were lower than the uncontrolled emissions, but probably because the samples were taken at different times. Concentrations of gaseous hydrocarbons ranged from 40 to 80 ppm, with hourly emission rates of 4 to 5.5 pounds (0.25 to 0.34 pound per ton). Concentrations of total aldehydes ranged from 0.7 to 5 ppm, with hourly emissions of 0.3 to 0.5 pound (0.02 to 0.03 pound per ton of saturated felt). Emissions of aldehydes were approximately 50 percent lower after the HEAF unit. Although tests at the inlet and outlet were not conducted simultaneously, some reduction in aldehydes could be caused by condensation and adsorption on the fiber mat.

Emissions of CO at plant B were somewhat lower than those at plant A, measuring 2.2 pounds per hour (0.14 pound per ton of product) before control. Hydrocarbon concentrations averaged 520 ppm, or 12.8 pounds per hour (0.8 pound per ton). Use of the fume incinerator gave a 24 percent reduction of hydrocarbons and no reduction in CO. As mentioned in the discussion of particulate emissions, this incinerator was burning No. 2 oil and was not operating under maximum control efficiency conditions.

4.3 ASPHALT BLOWING

4.3.1 Process Description

Although the processes are not always done at the same site, preparation of the asphalt is an integral part of felt saturating. Preparation consists of oxidizing the asphalt by bubbling air through liquid (430-500°F) asphalt from 1 to 4 hours. The industry refers to this operation as "blowing". Blowing may be done either in vertical cylindrical tanks, as shown in Figure 4.3, or in horizontal chambers. Because blowing time is shorter than in horizontal chambers, vertical stills are usually used. One or more blowing vessels may be operated simultaneously at a plant. They are usually connected to a common vent system and thus form a semicontinuous process.

In this operation, atmospheric air is compressed to about 10 to 15 psig and piped into a sparger in the bottom of the blowing vessel. Preheated asphalt is then pumped into the vessel and blowing is started. Blowing is continued until an asphalt with the desired melting point is achieved. The higher the desired melting point, the longer the blowing time. The blowing operation uses 1.5 to 2 cfm of air per gallon of asphalt charged.

The blowing operation removes volatile compounds from the asphalt and also oxidizes some compounds. Because the operation is exothermic, cooling water is required to control temperatures. The water is frequently applied to the walls of the vessel. Air, entrained asphalt droplets, gaseous hydrocarbons, carbon oxides, and some sulfur compounds are emitted from the blowing chambers. These emissions pass through a primary control device

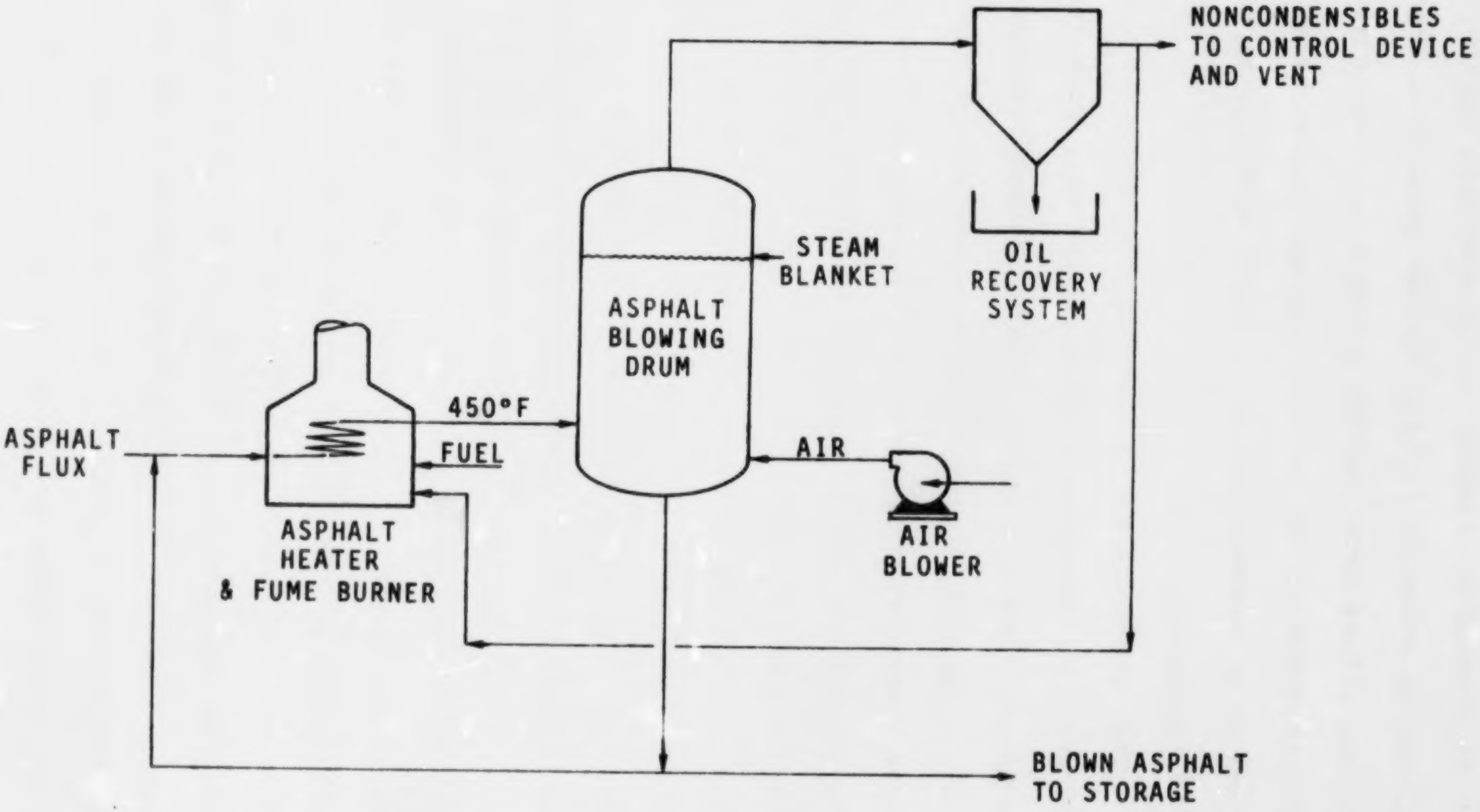
NONCONDENSIBLES
TO CONTROL DEVICE
AND VENT
OIL
RECOVERY
SYSTEM
STEAM
BLANKET
ASPHALT
BLOWING
DRUM
450°F
FUEL
AIR
ASPHALT
FLUX
ASPHALT
HEATER
& FUME BURNER
AIR
BLOWER
BLOWN ASPHALT
TO STORAGE

Figure 4.3 Air blowing of asphalt.[4.3]

such as a settling chamber or cyclone-type particulate collector, and an emission control device (usually a process heater furnace) before entering the atmosphere. Particulate matter (oil) captured in the primary control device is generally burned in an asphalt heater or mixed with raw asphalt.

4.3.2 Emissions

The cyclic nature of the blowing operation results in a wide range of emissions, which appear very high as the blowing starts and then decrease as the operation progresses. Particulate emissions also increase rapidly once the blowing chamber temperature exceeds 450°F. Uncontrolled asphalt losses from horizontal stills have been estimated to amount to about 3 to 5 percent of the amount charged. Losses from vertical stills are generally lower, on the order of 1 to 2 percent of the amount charged. One single reported field test showed 3.9 pounds of asphalt emitted per ton of asphalt charged after a settling chamber,[4.4] about 0.2 percent of the amount charged.

4.3.2.1 Particulate - Table 4.6 presents the particulate emission data obtained during tests at two blowing operations. Tests were conducted simultaneously before and after a fume incinerator at each plant. Emission data are presented on a concentration basis, as pounds per hour, and also as pounds per 1000 gallons charged (1000 gallons equal about 4 tons, based on density of 8 pounds per gallon). In all cases except the third test at plant C, only one still was operated at a time. Total emissions were thus related to a single batch of

Table 4.6 PARTICULATE EMISSIONS FROM ASPHALT BLOWING

	Asphalt Charged			Vent Gas[b]			Uncontrolled Particulate			Controlled Particulate[g]		
	1000 gallons	Melt Point, °F	Blowing time, min.	Flow MSCFM[c]	Temp., °F	Moist., %	gr/DSCF[d]	lb/hr	lb/1000 gallons[e]	gr/DSCF	lb/hr	lb/1000 gallons
Plant B	17.9	247	291	2.2	308	19.5	11.2	212	57.4	0.10	8.8	2.4
	17.9	132	132	3.2	263	5.1	0.3	8.1	1.0	0.43[f]	37.4[f]	4.6
Plant C	14.14	210	300	2.3	211	17.4	3.56	71.5	25.2	0.12	11.0	3.9
	14.14	130	133	2.1	206	16.9	1.48	25	3.9	0.023	1.9	0.28
	13.7[a]	130	127[a]	2.1	202	18.2	2.1	36.6	5.6	0.025	2.0	0.31

[a] Two stills - 14,140 gallons for 40 minutes at end of cycle and 13,500 gallons for 87 minutes (entire cycle), Avg. = 13,703 gallons.

[b] At inlet to afterburner - Outlet flows are 3 to 5 times as large because of combustion and dilution.

[c] 1000 cubic feet per minute corrected to 70°F and 29.92 in. Hg, dry basis.

[d] Grains per dry standard cubic foot.

[e] Pounds per hour times total blow time divided by gallons charged.

[f] Apparent afterburner malfunction.

asphalt. The samples of uncontrolled emissions were taken after a cyclone separator in each case.

As these data show, total uncontrolled vent gas flows are relatively low, about 2 to 3 thousand scfm. Moisture content of this gas stream is high, and temperature is in the 200 to 300°F range. Uncontrolled particulate emissions were much higher for the higher-melt-point asphalts as determined by tests over the total cycle; these emissions amounted to 25.2 and 57.4 pounds per 1000 gallons of blown asphalt (6.3 to 14.4 pounds per ton). Shorter blowing times required for the lower-melt-point asphalts resulted in much lower emissions, from 1 to 5.6 pounds per 1000 gallons (0.25 to 1.4 pounds per ton). Figure 4.4 shows the relationship between emissions and melting point. At both plants the vent gas entered a fume incinerator, which was used both to reduce emissions and to preheat the asphalt entering the blowing operation.

These units achieved particulate reduction efficiencies in the 85 to 95 percent range. Controlled emissions for the high-melt-point asphalt averaged 3.15 pounds per 1000 gallons (0.79 pound per ton); for the low-melt-point asphalt, emissions averaged 0.3 pound per 1000 gallons (0.075 pound per ton). The single outlet test at plant B for the low-melt-point asphalt yielded extraordinarily high emissions because of an apparent afterburner malfunction, which caused excessive emissions from the oil fired in this unit.

4.3.3.2 PPOM Emissions - Table 4.7 summarizes the PPOM emission

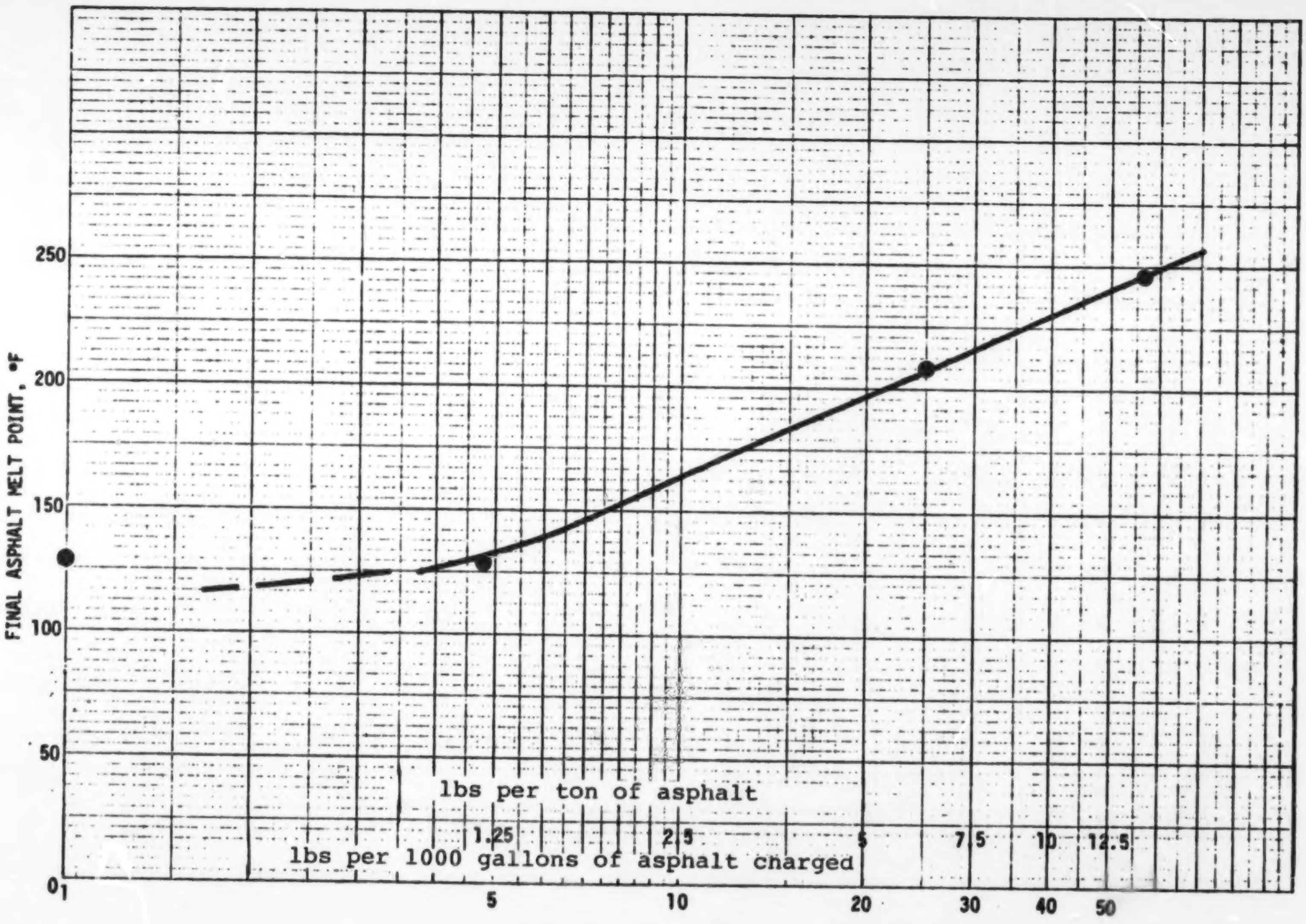

Figure 4.4 Relation of particulate emissions and asphalt melt point.

Table 4.7 PPOM EMISSIONS FROM ASPHALT BLOWING

Compound	Uncontrolled				Controlled[h]			
	Plant B		Plant C		Plant B		Plant C	
	µg/m^3	mg/hr	µg/m^3	mg/hr	µg/m^3	mg/hr	µg/m^3	mg/hr
Benz(c)phenanthrene	18.0	80.0	7.40	29.0	0.79	14.0	0.09	1.80
7,12-Dimethylbenz (a)anthracene	2.20	9.80	4.50	18.0	0.00	0.00	2.80	58.0
Benz(e)pyrene	14.0[a]	62.0[a]	0.17	0.67	0.25[a]	4.40[a]	1.00	21.0
Benz(a)pyrene			0.41	1.60			0.39	7.70
3-Methylcholanthrene	--	--	--	--	--	--	0.29	5.40
Dibenz(a,h)pyrene	2.80	12.0	--	--	0.40	7.00	0.02	0.45
Dibenz(a,i)pyrene	2.80	12.0	--	--	0.40	7.00	0.02	0.45
Total PPOM Emissions	175.8		49		32.6		95	
Percent of total particulate x 10^{-4}	1.8		1.5		8.2		19	

-- Non-detectable.

[a] Total benz(e)pyrene and benz(a)pyrene.

[b] Emissions pass through a process heater furnace. Unit B Utilized. Oil and Unit C utilized gas as auxiliary fuel.

data obtained at the two plants tested. Total hourly emissions ranged from 49 to 176 milligrams before the control device, and 33 to 95 milligrams after a fume incinerator. Both of these tests were run while high-melt-point asphalt was being blown and on the basis of particulate emission data would be expected to yield emission rates higher than those resulting from blowing of low-melt-point asphalt.

Tests of controlled and uncontrolled emissions were conducted simultaneously at the fume incinerator inlet and outlets. At plant B, the incinerator yielded 81 percent reduction in the total identified PPOM compounds. At plant C, emissions at the outlet were more than 2 times those detected at the incinerator inlet. This increase in PPOM emissions is probably due to partial reaction of some organic compounds in the fume burner.

PPOM percent of total particulates is also shown in Table 4.7. Before the fume incinerator, PPOM accounted for less than 0.0002 percent of total particulate; after the incinerator, PPOM accounted for between 0.00082 and 0.0019 percent of total particulate.

Published measurements of PPOM emissions from horizontal asphalt blowing stills showed benz(a)pyrene concentrations of less than 20 and 4 micrograms per cubic meter of exhaust gas before and after a steam spray-baffle control device.[4.4] In measurements before a control device, pyrene and anthracene were found in much higher concentrations: 5,800 and 310 micrograms per cubic meter, respectively.

4.3.3.3 Gaseous Emissions - Emissions of carbon monoxide and gaseous hydrocarbons from asphalt blowing processes cover a wide range, as shown in Table 4.8. This range is mainly due to the cyclic nature of the blowing process and the variable factors such as temperature and oxygen content that affect these emission rates. Carbon monoxide averaged 62 ppm (0.73 pound per hour) and 341 ppm (15.2 pounds per hour) before and after the fume incinerator, respectively, at plant B. At plant C, CO emissions were higher, averaging 1418 to 3956 ppm at the inlet and outlet, respectively.

At both plants carbon monoxide emissions increased by a factor of at least 10 after passage of the stream through the fume incinerator.

Controlled carbon monoxide emissions ranged from 15 pounds per hour at plant B to 179 pounds per hour at plant C (approximately 2 to 28 pounds per 1000 gallons or 0.5 to 7 pounds per ton of asphalt).

Gaseous hydrocarbon emissions ranged from 32 to 36.7 pounds per hour before the fume incinerator, and averaged 18.7 pounds per hour at the outlets. Controlled hydrocarbon emissions were equivalent to an emission factor of 2.5 pounds per 1000 gallons or 0.65 pound per ton of asphalt.

Data reported earlier on emissions from a horizontal still showed average concentrations of 900 ppm for CO and 2500 ppm for gaseous hydrocarbons. These data are similar to those found in the current tests on vertical stills.[4.4]

Table 4.8 GASEOUS EMISSIONS FROM ASPHALT BLOWING

	EMISSIONS	Uncontrolled			Controlled		
		ppm[a]	lb/hr	lb/ton[d]	ppm[a]	lb/hr	lb/ton[d]
Plant C	CO[a]						
	Range	358 - 7569			416 - 9106		
	Average	1418	13.5	0.52	3956	179	6.9
	HC[b]						
	Average	6733	36.7	1.4	656	16.9	0.66
	Aldehydes[c]						
	Average	7.4	0.08	0.0029	9	0.43	0.017
Plant B	CO						
	Range	3 - 179			3 - 1018		
	Average	62	0.73	0.022	341	15.2	0.47
	HC[b]						
	Range	3090 - 5900			410 - 1150		
	Average	4796	32.4	1.0	803	20.4	0.63

[a] Parts per million by volume. Controlled (incinerator outlet) emissions are more diluted than inlet emissions.
[b] Total gaseous hydrocarbons expressed as methane.
[c] Total aldehydes expressed as formaldehyde (CHOH).
[d] Based on a 2.2 hour blowing time. Multiply by 0.615 to convert to pounds per ton of saturated felt.

Note: Blower units at both plants controlled by fume incinerators.

Limited data on aldehydes show emissions in the range of 0.08 to 0.43 pound per hour before and after the fume incinerator. Again partial oxidation of some organic compounds in the incinerator yielded a higher outlet value.

Measurement of hydrogen sulfide at the fume incinerator inlet during tests at plant C yielded values of 0.3 to 0.7 part per million. The odor threshold for H_2S is approximately 0.0005 ppm.[4.5] Passage of the effluent through the fume incinerator would oxidize most of the H_2S to SO_2 and reduce the odor level considerably. This gas stream also contained 580 ppm of SO_2, yielding an average emission rate of 11.5 pounds per hour or 0.43 pound per ton of asphalt. The raw asphalt contained 2.1 percent sulfur.

4.4 MINERAL SURFACING APPLICATION

Approximately 700 pounds of mineral granules are applied to a ton of shingles (finished product). These granules are purchased from vendors and are virtually dustless. Points of granule application are not hooded or otherwise exhausted.

The top coating for shingles consists of colored granules, which are pressed into the hot asphalt coating. The opposite side of the roll is coated with a parting agent to prevent sticking.

Parting agents for roll roofing consist of talc, slag, mica, or sand. Except when sand is used, application of these materials is extremely dusty. Approximately 3 to 5 pounds of parting agent are applied per 100 square feet of roofing, depending on whether the agent is applied to one or both sides. Generation of dust is related to the fineness of the particles rather than the quantity applied. When excessive dust presents a problem at the work area, exhaust nozzles provide minimum control; ideally the entire application area is enclosed and equipped with exhaust devices. Emissions from the area can be captured with a fabric filter and returned to the system by screw conveyor. Fine washed sand is sometimes used. This agent is more costly than talc, but creates less dust.

Emission rates from these application operations are not reported in the literature. The control devices commonly used (fabric filter) are more than 99 percent efficient, however, and emissions from this source should not present a problem.

4.5 HOT ASPHALT STORAGE

Roofing manufacturers generally store asphalt in a liquid state in fixed-roof tanks. Heaters maintain the asphalt at a usable temperature of 350 to 400°F. Emissions from storage areas depend on storage temperature, properties of the asphalt, and throughput of the tanks. Although emissions are normally not visible, they are odorous and may be a problem during filling operations. Some manufacturers vent the tanks to an afterburner where the hydrocarbons are oxidized. Actual emissions are unknown. Table 4.9 presents an analysis of gases emitted from a paving asphalt storage tank during filling. The total quantity emitted would vary directly with the quantity of asphalt pumped into the tank. Heavy hydrocarbons would thus

Table 4.9 ANALYSIS OF VAPORS DISPLACED DURING FILLING 85/100 PAVING-GRADE ASPHALT INTO A FIXED-ROOF TANK[a],4.6

Component	Volume,%
Methane	Trace
Ethane	Trace
Heavy hydrocarbons (28° API gravity)	0.1
Nitrogen	67.3
Oxygen	13.0
Carbon dioxide	1.4
Water	18.2
Argon	Trace

[a] Sample was collected over a 3-1/2 hour filling period. Noncondensables were analyzed by mass spectrometer. Condensable hydrocarbons were separated from the steam, and gravity and distillation curves were determined.

amount to about 4 cubic feet per 30,000 gallons of asphalt (0.01 pound per ton of asphalt, based on an assumed molecular weight of 120).

4.6 SAND DRYER

Sand, or another type of filler, is blended with asphalt to form a slurry, which is applied at a controlled thickness to the saturated felt. The sand acts as a binder to stabilize the asphalt. Moisture content of the sand is about 5 percent by weight as stored; before blending, the sand must be dried. Drying is done either in a direct-fired rotary dryer or, more commonly, in an indirect, heated, baffled column. Inorganic particulate emissions in the form of sand result from the direct-fired drying operation.

5.0 CONTROL TECHNOLOGY AND COSTS

The manufacture of asphalt roofing generates two basic air pollutants: gaseous and condensible hydrocarbons from the saturator and blowing operations, and particulate matter from the application of mineral coating agents. Information obtained in plant visits and discussions with industry personnel indicates that the hydrocarbon emissions are by far the most difficult to control and cause the greatest emission problem. Small amounts of sulfur compounds and asphaltic odors are also emitted.

No control techniques have been developed specifically for PPOM compounds, and no information is available on the fate of these compounds as they pass through control systems used in this industry.

5.1 CONTROL OF SATURATOR EMISSIONS

Many systems have been used over the years to reduce emissions from the saturator, largely on a trial-and-error basis. Table 5.1 summarizes the devices currently in use and indicates their relative popularity.

Table 5.1 CONTROL EQUIPMENT USED ON SATURATORS

Device	Percent of total lines[a]
Low-voltage ESP	12
ESP/scrubber combination	3
Scrubber	3
Afterburner	52
HEAF (High Energy Air Filter)	30

[a] Based on a survey of 61 operating lines in late 1973. Value is percent of lines surveyed, not percent of production.

5.1.1 Electrostatic Precipitators

Low-voltage (approximately 10,000 volts) electrostatic precipitators, as shown in Figure 5.1, have been used with some success to reduce particulate emissions.[5.1] Control efficiencies are reportedly in the low 90 percent range, however, and maintenance of electrostatic precipitators is difficult because of the cohesive tar-like characteristics of the particulate. Additionally, water sprays used in the ducts form an oil emulsion that is difficult to break. Recently, the use of detergents has reduced this problem.

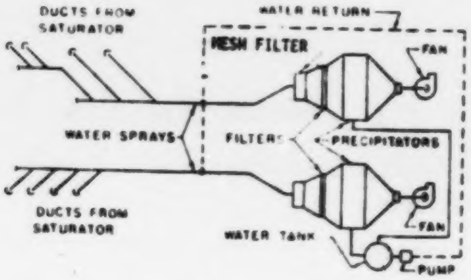
DUCTS FROM SATURATOR
WATER RETURN
MESH FILTER
FAN
WATER SPRAYS
FILTERS
PRECIPITATORS
DUCTS FROM SATURATOR
WATER TANK
FAN
PUMP

Figure 5.1 Flow diagram for low-voltage electrostatic precipitators.[5.1]

The industry has recently renewed its interest in low-voltage precipitators because of fuel shortages, costs of afterburners, and the water pollution aspects of scrubbing. In the newer installations a fiber mesh precleaner is frequently used, and the system is installed in modules to facilitate cleaning and maintenance.[5.2] Vent gas velocities across the precipitator are in the range of 2.5 to 3.3 feet per second.

5.1.2 Scrubbers

Low-energy scrubbers are not ideal for control of saturator emissions, since their collection efficiencies in the 70 percent range are not adequate for eliminating opacity and odors. Use of more efficient venturi scrubbers has generally been avoided because of high operating costs and problems of water pollution control.

5.1.3 Afterburners

The most popular control system currently used for both particulate and gaseous control is fume incineration or afterburning. Although incineration can be done in the presence of a catalyst at approximately 800°F, the advantage of this relatively low operating temperature is more than offset by problems associated with catalyst fouling. Direct-flame afterburners can remove up to 99 percent of the hydrocarbon emissions when designed for 0.3 second retention at 1400°F.[5.3] Fuel can be either natural gas or No. 2 fuel oil. Users of direct-flame afterburners report that odors associated with the saturation process are completely eliminated.[5.4,5.5] If afterburners are properly designed and operated, they provide a satisfactory means of controlling saturator emissions. Availability and cost of fuel are potential problems.

Afterburners are installed both with and without heat recovery, according to the decision of individual plant operators. In general, heat recovery is more economical for new facilities, but it is not always possible to achieve maximum recovery since the afterburner exhaust oftentimes contains more heat than the process requires. Maximum heat recovery is realized only when the roofing manufacturing facility also produces the paper (dry felt), since the felt-drying process requires copious quantities of heat for generation of steam to be used in the drying drums. Afterburner exhaust can be used for generating this steam or the 200 to 1400°F afterburner exhausts can be mixed with ambient air, the temperature lowered to 450°F, and the exhaust stream blown on the exposed side of the felt as it turns on the drying drum. It has been reported that a typical felt manufacturing process uses 14 to 18 million

BTU per hour.[5.4] About 36 million BTU per hour is required to treat 25,000 cfm of saturator exhaust at 1400°F. Thus, maximum heat utilization is in the range of 40 to 50 percent. Approximately 40 percent recovery is also realized from a properly designed exhaust gas preheater. Recovered heat can also be used to preheat asphalt in the saturators and/or in the blowing operation.

Most afterburners use natural gas as fuel, with light oil as standby when gas is on an interruptable basis. Fuel costs are variable and because of the projected scarcity of natural gas are in a state of flux. Fuel costs were approximately $1.25 per million BTU for natural gas and $2.10 per million BTU for No. 2 fuel oil (30¢ per gallon) in late 1973 in the Midwest.

Process heaters used to preheat the asphalt (either raw or blown) can also function as fume incinerators. These devices should yield control efficiencies comparable to those of an afterburner system. High efficiencies, however, require careful introduction of the vent gases to ensure good mixing and maintenance of a firebox temperature of a least 1300°F. Process heaters in which firebox temperatures are controlled by the exit temperature of the material being heated may yield low fume control efficiencies when the firebox temperature is reduced.

5.1.4 Mesh Filters

The search for efficient devices to control oily mists led to the development of the High Energy Air Filter (HEAF). This device, shown in Figure 5.2, consists of a slowly moving glass-fiber filter pad through which the process exhausts pass. The thickness and number of fibers in the pad result in a high degree of impingement, yielding reported collection efficiencies as high as 96 to 98 percent at a pressure drop of 24 inches of water.[5.6] Efficiency is related to face velocity. As commonly used with a 1-inch-thick pad, the HEAF operates with pressure drops in the range of 20 to 25 inches of water and face velocities of 400 to 500 feet per minute. The fiber pad is in roll form, and as the portion of the pad exposed to the gas stream becomes loaded with particulate, the roll advances to expose a clean portion. The entire roll is disposed of after use. Some saturator installations also utilize a stationary steel wool demister pad after the HEAF to further reduce carryover. Because of their oil content, disposal of the rolls may be a problem in some landfill operations.

Cooling of the gas stream is required to collect condensible compounds. Cooling is not generally done by dilution with ambient air because this greatly increases the amount of air to be handled. Although the HEAF cannot remove gaseous emissions and vapors, improvement in odor control has been reported, with odor unit reductions in the range of 50 to 90 percent.[5.6]

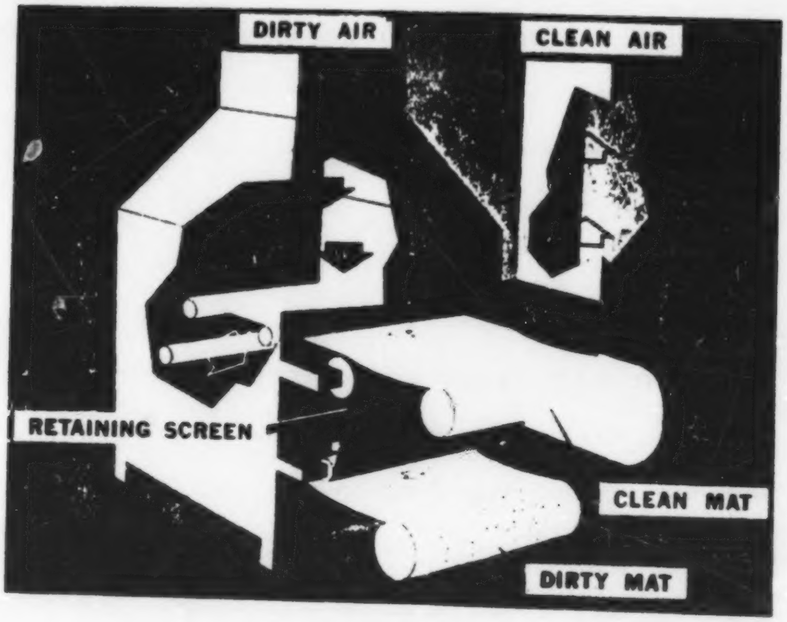
DIRTY AIR
CLEAN AIR
RETAINING SCREEN
CLEAN MAT
DIRTY MAT

Figure 5.2 Flow diagram for HEAF.[5.7]

Mist eliminators such as the Brink H-E type have not been used on saturator emissions because of the high viscosity of the particulate. These systems are designed so that the particulate agglomerates in the filter medium and eventually flows downward to the base for collection. Although the saturator emissions are believed to be too viscous to flow from the mesh, operations at slightly increased temperatures could reduce this problem.

5.1.5 Costs of Saturator Emission Control

Although the costs of controlling emissions from asphalt saturators depend on many factors, there is generally a direct relationship between control costs and exhaust volume. Factors that affect exhaust volume are the area of saturator hood openings, asphalt characteristics (relating to fire hazards), width of the felt, and line speed. Based on published data, estimated installation and operating costs for a "typical" saturator are given in Table 5.2.

One manufacturer has standardized new saturator exhaust rates at 10,000 acfm (8000 scfm).[5.8] Compared with a more typical exhaust rate of 20,000 to 30,000 scfm, such a design would yield substantial savings in operation of a control device. There are, however, some conflicting views regarding minimum exhaust rates. Although asphalt does not have a lower explosive limit (LEL), many of the constituents do.[5.9] Without knowledge of specific process weight rates, hood configurations, and saturator construction details, the required exhaust rates

Table 5.2 ECONOMICS OF VARIOUS SYSTEMS FOR CONTROLLING EMISSIONS FROM ROOFING PLANT SATURATORS

(Basis: 6000 hr/yr operation at 30,000 acfm)

PROCESS	HEAF	Low voltage precipitator electrostatic	Mist eliminator	Incinerator	Incinerator with heat exchanger-52%	Low-energy wet scrubber	High-energy venturi scrubber
Particulate removal efficiency, %	96-98	90-95	99	99	95-99	85	90-95
Opacity removal	Acceptable	Acceptable	Unknown	Acceptable	Acceptable	Unacceptable	Unacceptable
Odor removal	Accpetable	Acceptable	Unknown	Acceptable	Acceptable	Unacceptable	Unacceptable
Installed cost[d]	$234,000	$190,000	$162,000	$ 87,000	$144,000	$115,000	$150,000
Operating cost, $/yr[b]	22,000	3,100	58,600	385,000[c] 647,000[d]	180,000[c] 203,000[d]	65,900	13,400
Maintenance cost, $/yr	7,000	14,600	4,900	1,200	16,100	6,100	2,400
Total operating and maintenance costs, $/yr	29,000	17,700	63,500	386,200	186,100	72,000	15,800

[a] Cost upgraded from original table by Chemical Engineering Cost Index, Chem Engineering, November 12, 1973, McGraw-Hill and by vendor contacts.

[b] Operating maintenance upgraded at 5 percent inflation per year.

[c] Based on $1.25 per million BTU fuel cost for natural gas.

[d] Based on $2.10 per million BTU fuel cost for No. 2 oil.

Note: Based on up-dating of data in Reference 5.6.

are difficult to determine. For this reason, operating costs could vary widely from those shown in Table 5.2. Costs of operating an incinerator or afterburner are especially variable depending on exhaust gas rates; these costs could be as low as $70,000 per year instead of $180,000.

In summary, two control systems have proved most effective to date in controlling particulate emissions from saturator exhausts: direct-flame afterburners and HEAF units. Low-voltage precipitators have found increased popularity in the last year and are being installed on some existing plants. Generally, HEAF's are used on existing plants where heat recovery is not a practical design consideration. Most new installations utilize afterburners with heat recovery.

5.2 CONTROL OF ASPHALT BLOWING EMISSIONS

Emissions from asphalt blowing are very similar to those from saturators; concentrations are much more variable, however, and tend to be much higher at peak periods. Conversion from older horizontal stills to vertical blowing stills significantly reduce emissions and facilitates control. Almost all stills are now vertical. Existing controls consist almost entirely of fume incineration in a process heater or afterburner.[5.10] Heat generated by the afterburner is used to preheat asphalt for the blowing and saturator operations. These furnaces are oil- or gas-fired, and particulate removal efficiencies generally range from 80 to 90 percent. In all stills surveyed during this study, emissions were controlled by combustion in direct-fired units.

One manufacturer is contemplating installation of a HEAF on an asphalt-blowing operation, but there are no existing installations from which to collect data. A Brink mist eliminator has reportedly been installed on a blowing operation at a west coast refinery, but no test data are available.[5.8]

Total exhaust gas flow rates from blowing operations are in the range of 2000 to 3000 scfm per still (150 scfm per 1000 gallons). Because the volume is considerably smaller than flow from the saturator, blowing is less expensive to control; operating costs for an incinerator amount to about one-tenth of the costs incurred on a saturator.

5.3 CONTROL OF SURFACING AGENTS

Handling of sand, talc, and mica parting agents emits fine dust particles during receiving operations and application. These emissions are well controlled with fabric filters. Because use of a fabric filter with pneumatic receiving and handling systems is an integral part of the plant process, its cost cannot be considered a control cost. Particulate control efficiencies above 99 percent are common for these devices as applied to these emissions. Installed costs of control equipment are in the range of $2.65 per cfm (1973).

The industry considers sand drying to be a minor source of particulate (fine sand). Newer plants no longer dry sand but purchase it at a specified moisture content. Where sand is dried, however, fabric filters can control particulate emissions very effectively, with efficiencies of approximately 99 percent.

5.4 CONTROL OF HOLDING TANK EMISSIONS

Because emissions from this source are relatively low, most facilities have no control system. One plant vents fumes from the holding tank to an incinerator. The most common control method, however, is merely to hold the asphalt at a low temperature (approximately 350°F) to reduce vapor formation.

6.0 IMPACT OF ATMOSPHERIC EMISSIONS

The impact on the environment of atmospheric emissions from the manufacture of asphalt roofing depends on: 1) the types and quantities of emissions, 2) the resulting atmospheric concentrations of the emissions due to dispersion, 3) the location of the plant in regard to surrounding land use, and 4) the effects of the pollutants. In this chapter these factors are discussed in relation to the total impact of an asphalt manufacturing plant upon the surrounding area.

6.1 EMISSION SUMMARY

Emissions from asphalt roofing processes, described earlier in this report, are summarized in this section.

6.1.1 Particulate Emissions

Organic particulate matter is emitted mainly during asphalt blowing and saturation of the felt. Emissions from these operations contain polycyclic hydrocarbons, some of which are known to be carcinogenic. Consequently, these emissions are especially significant in evaluating potential environmental impact.

Table 6.1 summarizes the particulate and PPOM emission data presented in Chapter 4.0. These data, based on measured emissions, show that saturators emit on the average 6.3 and

Table 6.1 PARTICULATE AND PPOM EMISSION DATA SUMMARY

Operation	Particulate, lb/ton of felt		PPOM,[a] % of particulate x 10^{-4}	
	Uncontrolled	Controlled	Uncontrolled	Controlled
Saturating	3.9-8.7	1.2-4.2	1.2-4.8	2.0-4.4
Average	6.3	2.7	3.0	3.2
Blowing[b]	3.9-8.9 0.15-0.86	0.046-0.60	1.5-1.8	8-19
Average	4.5	0.32	1.65	13

[a] Seven identified compounds only. BaP is approximately 10% of this quantity.

[b] Pounds per ton of asphalt converted to pounds per ton of saturated felt by multiplying by 0.615 (product contains 61.5% asphalt).

[c] High-melt-point asphalt.

[d] Low melt point.

NOTE: Range values are averages of test data.

2.7 pounds per ton of saturated felt with no control and with average control, respectively. A well-controlled plant would emit about 0.6 pound per ton, at a control efficiency of 90 percent. PPOM emissions average approximately 0.0003 percent of the particulate both before and after a control device.

Although particulate emissions from asphalt blowing are more variable, they average 0.27 pound per ton of saturated felt with a fume incinerator control device. Uncontrolled blowing operations are not in use. PPOM compounds account for an average of 0.0013 percent of the particulate.

6.1.2 Gaseous Emissions

Table 6.2 summarizes measured gaseous emission data. These data show that only limited control is achieved by the fume incinerators and HEAF unit tested. In blowing operations, gaseous emissions actually increased after passage of effluent through fume incinerators. The reported concentrations of hydrocarbons represent total hydrocarbons as measured with a flame ionization detector; no further characterization of these compounds was obtained. Sulfur dioxide emissions vary with sulfur content of the asphalt. A single measurement of 0.43 pound per ton of asphalt (0.26 pound per ton of saturated felt) was reported when the asphalt contained 2.1 percent sulfur. Thus, only a small portion of the sulfur in the asphalt is emitted.

6.2 POLLUTANT EFFECTS

Effects of pollutants from asphalt roofing manufacturing

Table 6.2 GASEOUS EMISSION SUMMARY

(lb/ton of saturated felt)

Process	CO		HC[a]		Aldehydes[b]	
	Uncontrolled	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled
Saturating						
Range	0.14-5.1	0.16-3.5	0.26-0.84	0.34-0.64		
Average	2.6	1.8	0.55	0.49	0.033	0.017
Blowing[c]						
Range	0.013-0.32	0.29-3.2	0.61-0.86	0.39-0.41		
Average	0.16	1.7	0.43	0.4	0.0017	0.01

[a] Total gaseous hydrocarbons expressed as methane.
[b] Aldehydes expressed as formaldehyde.
[c] Pounds per ton of asphalt blown converted to pounds per ton of saturated fat.

NOTE: Range values are averages of test data.

processes depend on the resulting concentrations in ambient air and on possible interactions with other compounds in the air. Of prime concern is particulate matter; emissions should not cause ambient air concentrations to exceed Federal and/or State ambient air levels. The Federal 24-hour primary and secondary particulate standards are 260 and 150 $\mu g/m^3$, respectively.[6.1] Concentrations in excess of these values will reduce visibility, cause soiling, and possibly affect human health. Since particulate matter in asphalt plant emissions is very fine, its potential for health effects is increased by the possibility of retention in the lung. Figure 6.1 shows percent retention of particles in the lung as a function of particle size. The organic (asphaltic) nature of the particulate matter also contributes to a distinctive odor associated with asphalt.

The PPOM content of the particulate is of particular concern because of possible carcinogenic effects. Table 6.3 shows the potential carcinogenic effects of selected PPOM compounds found in emissions from asphalt processing.

An acceptable ambient air level for PPOM compounds has not been established. Epidemiological data, based on benz(a)pyrene (BaP) as an indicator of PPOM, indicate that a two-thirds reduction in BaP (6 $\mu g/1000\ m^3$ to 2 $\mu g/m^3$) could reduce the lung cancer rate by 20 percent.[6.3] Seasonal peaks of 79 $\mu g/1000\ m^3$ in Osaka, Japan; 12 $\mu g/1000\ m^3$ in Los Angeles; and 76 $\mu g/1000\ m^3$ in Birmingham have been reported.[6.3] A

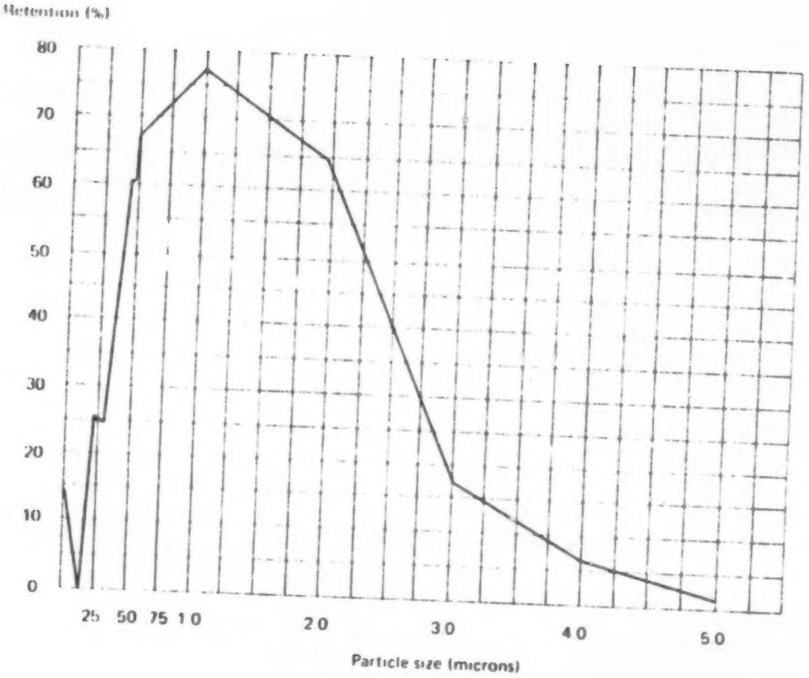

Figure 6.1 Retention of particulate matter in lung in relation to particle size.[6.2]

Table 6.3 CARCINOGENIC POTENTIAL OF SELECTED ASPHALT ROOFING EMISSION COMPOUNDS[6.3]

Compound	Carcinogenicity[a]
Benz(a)phenanthrene	+++
7,12 - Dimethylbenz(a)anthracene	++++
Benz(e)pyrene	-[b]
Benz(a)pyrene	+++
3 - Mehtylcholanthrene	++++
Dibenz(a,h)pyrene	+++
Dibenz(a,i)pyrene	+++

- Not carcinogenic
+++, ++++ Strongly carcinogenic

[a] Code of relative carcinogenicity:

[b] References 6.2 and 6.3 show a weak to inactive carcinogenic effect for benz(e)pyrene (BeP). Primary reason for inclusion in the test matrix is the concurrent presence of BeP and BaP.

median value of 6.6 µg/1000 m^3 was obtained for 100 U.S. cities in 1959.[6.4] Data obtained in 7 U.S. cities (not including a Birmingham-type city) in 1969 indicated concentrations of benzene-soluble* particulate (annual average) ranging from 6 to 25 µg/1000 m^3. An industrial hygiene standard of 150 µg/1000 m^3 for BaP has been proposed in Russia.[6.5]

The effects of carbon monoxide are health related.[6.6] The Federal 1-hour ambient air standard for CO is 40 µg/1000 m^3.

Gaseous hydrocarbons affect visibility through their participation in photochemical smog reactions, cause odors, and potentially affect health.[6.7] One would expect only a small percentage of compounds emitted in the asphalt roofing process to be photochemically reactive. The low efficiencies of the fume incinerators were probably caused by unburned methane or light ends in the fuel oil. The Federal standard for nonmethane hydrocarbons is 160 µg/m^3, based on a three-hour average.

Sulfur dioxide can affect visibility, construction materials and other substances, and human health. In conjunction with the fine particulate matter, SO_2 produces adverse health effects that are dependent on concentration. The Federal SO_2 standard for a 24-hour period is 260 µg/m^3; for a 3-hour period, it is 1300 µg/m^3.

Aldehydes, also precursors and products of photochemical reactions, are assigned a general level of significance at

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* Indicative of total amount of organic matter present, not necessarily equivalent to polycyclic matter.

160 μg/m^3 over a 1-hour period.[6.1] Formaldehyde, one of the more significant aldehydes in terms of effects, induces eye irritation or physiological response (optical chronaxy) at about 70 μg/m^3.[6.7]

6.3 AMBIENT AIR CONCENTRATIONS

Atmospheric concentrations of pollutants emitted by asphalt roofing processes must be known before environmental effects can be assessed. A dispersion model utilizing emission data provides an estimate of maximum ground-level concentrations at various times and distances from point of emission.

6.3.1 Method of Calculation

The Gifford-Pasquill atmospheric dispersion model yields "first approximations" of short-term maximum concentrations as a function of atmospheric stability and effective stack height.[6.8] This dispersion calculation program incorporates the Briggs plume rise equation, which generally yields a higher effective stack height than does the Holland equation. In evaluation of plants for which physical stack heights are fairly short, changes in effective stack height due to plume rise have a significant effect on the resulting calculated ground-level concentrations. Turner concludes that the general equations are accurate within a factor of 3 for (a) receptors within several hundred meters exposed under all classes of atmospheric stabilities, and (b) receptors within several thousand meters under neutral or moderately unstable conditions.[6.8] The PTMAX computer program, which incorporates this dispersion model, was used to calculate ambient air concentrations resulting from asphalt roofing processes under a variety of conditions.

The following parameters were used as input data for the dispersion calculation:

physical stack height = 9.1 meters (30 feet)*

stack gas exit velocity = 15 m/sec

inside stack diameter = 1 meter

wind speed = 0.5 to 10 m/sec

atmospheric pressure = 1013 mb (1 atmosphere)

stack gas temperature = 348°K

ambient temperature = 293°K

With these parameters, ambient air concentrations were determined as functions of various emission rates, wind speeds, and atmospheric stabilities.

6.3.2 Calculated Ambient Air Concentrations

Figure 6.2 shows the maximum short-term ambient air concentrations resulting from selected stack emission rates. These concentrations are calculated to occur under atmospheric stability classes of C and D, and at wind speeds in the 7 to 10 m/second range. Applying this information to asphalt roofing manufacture requires the use of representative emission rates for typical process combinations and control efficiencies. Production rates in the industry vary over a wide range, from 1 to 2 tons per hour to approximately 20 tons of saturated

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* Many stacks are higher than 30 feet. However, some emissions such as fugitive leaks from buildings are at points much lower; 30 feet represents an approximate average height.

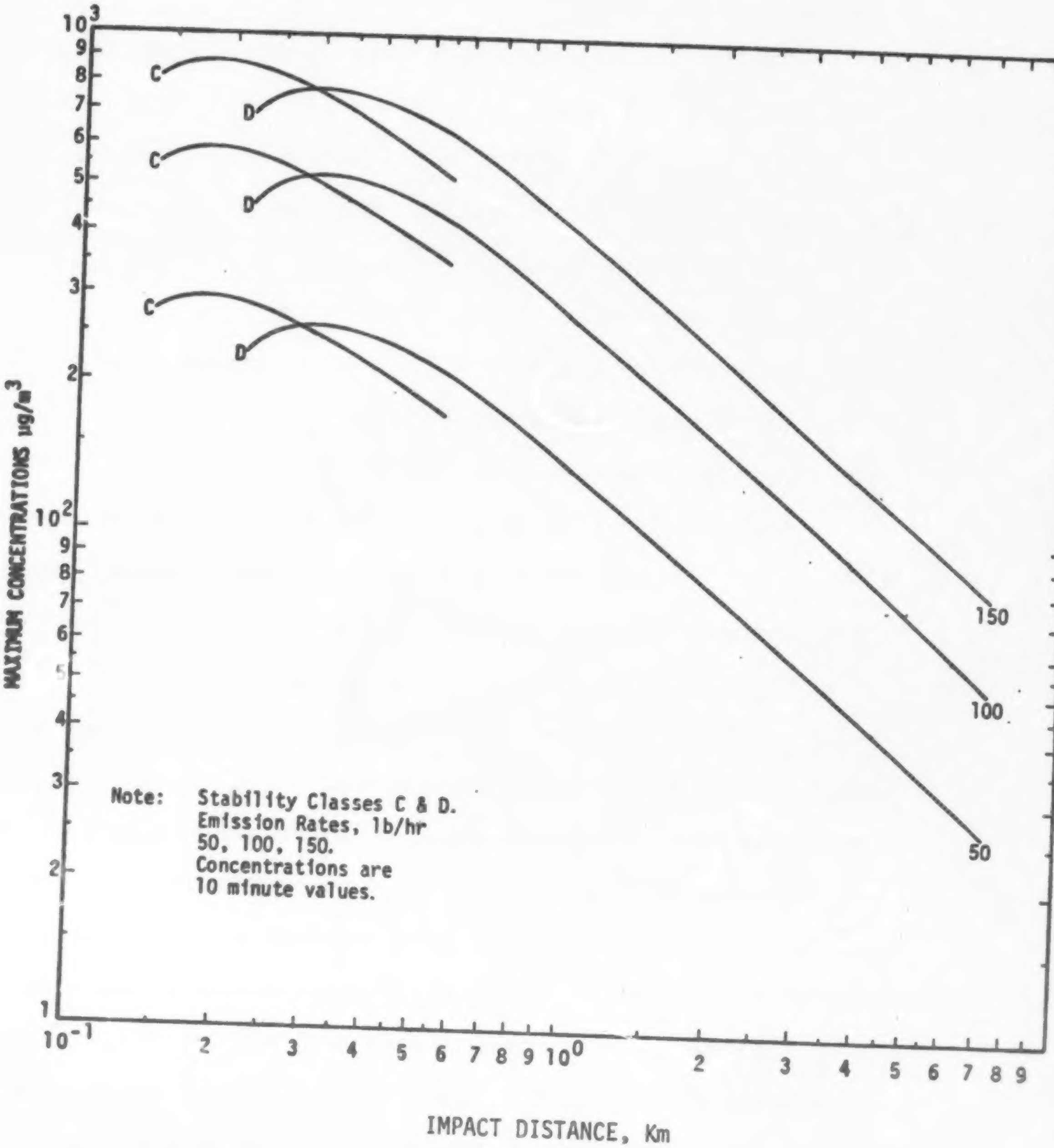


Figure 6.2 Estimated atmospheric concentrations of emissions from asphalt roofing plants.

felt per hour. The average size plant produces less than 5 tons of product per hour. Newer plants tend to operate a number of saturation lines in parallel, with typical average production rates between 10 and 20 tons per hour. For these calculations a rate of 10 tons per hour was selected.

Table 6.4 summarizes the resulting particulate and PPOM ambient air levels for a 10-ton-per-hour plant employing various combinations of processing and control equipment. For a 20-ton-per-hour plant, the resulting concentrations would be twice those calculated in this illustration. These data show that uncontrolled particulate concentrations amount to 150 $\mu g/m^3$ on a 24-hour basis for a saturator. With a blowing operation at the same site the concentration would increase to about 156 $\mu g/m^3$. PPOM concentrations up to 0.45 $\mu g/1000\ m^3$ could be reached on a 24-hour basis. These data represent typical average values. Process difficulties and/or control equipment malfunctions on the blowing operation could increase emission levels many times.

The use of a plume rise equation such as the Holland equation, which gives a lower effective stack height; also increases the calculated ambient air concentrations by a factor of 2 or 3 beyond those shown in Table 6.4.

Ambient concentrations of gaseous pollutants emitted from the hypothetical 10-ton-per-hour plant are shown in Table 6.5 for various processing and control combinations. These data show that the maximum 1-hour CO concentration for

Table 6.4 ATMOSPHERIC CONCENTRATIONS OF PARTICULATE POLLUTANTS FROM A 10-TON/HOUR ASPHALT ROOFING PLANT[a]

Process and control combination	Emission rate		Atmospheric concentrations[b]		
	Total particulate, lb/hr	PPOM fraction X 10^{-6}	Total particulate, $\mu g/m^3$		PPOM, $\mu g/1000\ m^3$
			10 min	24 hr[c]	24 hr
Saturator uncontrolled	63	3	380	150	0.45
Saturator controlled	27 6.3[d]	3	160 38[d]	64 16[d]	0.19 0.05[d]
Blower controlled	3.2	13	19	6	0.08
Saturator and blower controlled	30.2 9.5	6.5	180 58	72 23[d]	0.5 0.15[d]

[a] Based on data in Table 6.1.
[b] Atmospheric stability condition C.
[c] Twenty-four-hour values are extrapolated from 10-minute values (Ref. 6.8).
[d] Achieved with control device operating at 90% efficiency.

Table 6.5 ATMOSPHERIC CONCENTRATIONS OF GASEOUS POLLUTANTS FROM A 10-TON/HOUR ROOFING PLANT[a]

Process and control combination	Emission rates, lb/hr			Atmospheric concentrations,[b] μg/m³					
				CO		HC		Aldehydes	
	CO	HC	Alde-hydes	10 min	1 hr[c]	10 min	3 hr[c]	10 min	1 hr[c]
Saturator uncontrolled	26	5.5	0.3	160	115	33	19	1.8	1.3
Saturator controlled[d]	26 2.6	5.0 0.5	0.17	160 16	115 12	30 3	18 2	1.0	0.7
Blower controlled	1.6	4	0.1	10	7	24	14	0.5	0.4
Saturator and blower controlled	27.6 4.2	9.0 4.5	0.27	170 26	122 19	54 27	31 16	1.5	1.1

[a] Based on data in Table 6.2.
[b] Atmospheric stability condition C.
[c] Extrapolated from 10-minute values. Note: HC time is 3 hr; others are 1 hr.
[d] High value is emission with only particulate control device. Lower value is emission with afterburner at 90% efficiency.

this hypothetical plant is 0.12 mg/m^3, total hydrocarbons (3-hour average) amount to 31 μg/m^3, and aldehydes 1.3 μg/m^3. Again, with respect to larger plants, ambient air concentrations would increase in proportion to emissions.

6.4 EMISSION IMPACT

The overall impact of an average-sized asphalt roofing plant with controls usually applied in this industry to meet state and local particulate regulations is not great under typical operating conditions. Malfunctions and process difficulties could cause ambient air concentrations to exceed the standards. These plants do, however, contribute to the overall atmospheric burden, and the potential contribution of plants located in densely populated areas, even with control equipment, should not be ignored. Particular attention should be given to plants with inadequate hooding over the saturator, since this deficiency causes higher-than-average ground-level emissions and resulting higher ambient air concentrations, usually with accompanying odor problems.

Possible synergisms in interactions between the organic particulate matter and gases in the atmosphere are difficult to evaluate, since so little is known about effects of these substances. The presence of PPOM and fine particulate in air presents the possibility of increased lung retention of carcinogenic compounds. The percent of PPOM in the various size fractions was not determined in the analyses done for this study because of the large sample volume required for this determination. Therefore, although any extraordinary health effects of the particulate matter emitted in the manufacture of asphalt roofing remain unidentified, such effects are possible.

7.0 REFERENCES

2.1 Asphalt and Tar Roofing and Siding Products, Summary for 1972. U. S. Dept. of Commerce, Series MA-29A (72)-1, and earlier summaries.

2.2 Bureau of the Census, Census of Manufacturers: 1972.

2.3 Bureau of the Census, Census of Manufacturers: 1967.

2.4 Statistical Abstract of the United States -1972, 93rd Edition, U. S. Dept. of Commerce.

2.5 U. S. Bureau of Census, Census of Construction Industries, 1967, Series CC 67-I-1B.

3.1 Berry, G. W. Roofing Materials. In: Kirk-Othmer Encyclopedia of Chemical Technology, Volume 17, 2nd Edition, Standen, A. (ed.). New York, John Wiley & Sons, Inc., 1967.

3.2 Ibid, Volume 2, p. 763-806.

3.3 Ibid, p. 787.

3.4 Abraham, H., Asphalts and Allied Substances; Volume III. Princeton, D. Van Nostrand Co., Inc., 1963. p. 133-194.

3.5 Ibid, p. 231-241.

3.6 Ibid, p. 366 - 415.

3.7 Ibid, p. 64-119.

4.1 Weiss, S. M. In: Air Pollution Engineering Manual, Second Edition, Danielson, J. A. (ed.). National Air Pollution Control Administration. Raleigh, North Carolina. Public Health Service Publication 999-AP-40. 1967. p. 390.

4.2 Bay Area Air Pollution Control District. Test Report Submitted to Johns-Manville on March 9, 1973.

4.3 Hoiberg, A. J., et. al. Asphalt. In: Kirk-Othmer Encyclopedia of Chemical Technology, Volume 2, 2nd Edition, Standen, A. (ed.). New York, John Wiley & Sons, Inc., 1967. p. 762-806.

4.4 Von Lehmden, D. J., R. P. Hangebrauck, and; J. E. Meeker. Polynuclear Hydrocarbon Emissions from Selected Industrial Processes. J. Air Pollution Control Assoc. 15: 306-312, July 1965.

REFERENCES (Continued)

4.5 Leonardes, G. et. al. Odor Threshold Determination of 53 Odorant Chemicals. J. Air Pollution Control Assoc. 19:91-95, February 1969.

4.6 Weiss, S. M. In: Air Pollution Engineering Manual, Second Edition, Danielson, J. A. (ed.). National Air Pollution Control Administration. Raleigh, North Carolina. Public Health Service Publication 999-AP-40. 1967. pp. 642 & 644.

5.1 Goldfield, J., and R. G. McAnlis. Low Voltage Electrostatic Precipitators to Collect Oil Mists from Roofing Felt Asphalt Saturators and Stills. American Industrial Hygiene Assoc. J., p. 411, July-August 1963.

5.2 Private communication. United Air Specialists Inc., Cincinnati, Ohio. Feb., 1972.

5.3 Rolke, R. W. et al. Afterburner Systems Study. Shell Development Company. Emeryville, California. EPA Contract EHS D-71-3. p. 18-20; 169-178. Aug., 1972 NTIS No. PB-212 560.

5.4 Private communication with industry spokesman, November 1972.

5.5 Private communication with Mr. William Greig, GAF Corp., New York, New York. November 16, 1972.

5.6 Goldfield, J., V. Greco, and; K. Gandhi. Glass Fiber Mats to Reduce Effluents from Industrial Processes. J. Air Pollution Control Assoc. 20:466-469, July 1970.

5.7 High Energy Air Filter for Reducing Industrial Effluents, Filtration Engineering. May 1970.

5.8 Private communication with Mr. David R. Duros, Monsanto Enviro-Chem Systems, Inc., Cincinnati, Ohio. November 21, 1972.

5.9 Handbook of Industrial Loss Prevention (2nd Edition). Factory Mutual Engineering Corp., New York, 1967. p. 42-4.

5.10 American Fume Burner Cleans Air. The Oil and Gas Journal, p. 57-58, March 20, 1972.

REFERENCES (Continued)

6.1 Federal Register, Vol 36, No. 84, April 30, 1971.

6.2 Preliminary Air Pollution Survey of Organic Carcinogens, NAPCA Pub. No. APTD 69-4[illegible], Oct., 1969, Raleigh, N. C.

6.3 Particulate Polycyclic Organic Matter. National Academy of Sciences. Washington, D. C., 1972.

6.4 Sawicki, E., et. al. Benzo (a) pyrene content of the air. American Ind. Hyg. Assoc. J. 21: 443-451, 1960.

6.5 Shabad, L. M., et. al. Possibility of Establishing Maximum Permissible Concentration of Benzpyrene in Air of Industrial Enterprises. Gigienai Sanitariya, 38 (4): 78-80, 1973.

6.6 Air Quality Criteria for Carbon Monoxide. National Air Pollution Control Administration, Washington, D. C. Publication Number AP-62. March 1970.

6.7 Air Quality Criteria for Hydrocarbons, National Air Pollution Control Administration, Washington, D. C. Publication Number AP-64. March 1970.

6.8 Turner, D. B. Workbook of Atmospheric Dispersion Estimates. National Air Pollution Control Administration, Cincinnati, Ohio. Public Health Service Publication No. 999-AP-26. 1969. 84p.

8.0 APPENDICES

A. Asphalt Roofing Plants in 1973 - SIC 2952

B. Emission Test Procedures and Results

APPENDIX A. LOCATION OF ASPHALT ROOFING PLANTS

Table A-1 presents a listing of asphalt roofing manufacturing plants by state in 1973. Total annual sales are also shown for each state. This listing is comprised mainly of plants with 20 or more employees. Plants which only produce blown asphalt are not included in this table.

This tabulation shows a grand total of 202 installations with annual sales of approximately $881 million. The 1972 Department of Commerce's Census of Manufacturers shows 233 establishments with total production value of approximately $1,000 million.

Information for Table A-1 was obtained from: 1) Asphalt Roofing Manufacturers' Association, 2) Economic Information Systems Inc. Report on SIC 2952 of April 22, 1974, and 3) the U.S. EPA National Emission Data Survey for 1972.

Table A-1 LISTING OF ASPHALT ROOFING PLANTS IN 1973[a]

SIC 2952

Company Name and Location		
Alabama		
Celotex Corp. Birmingham, Jefferson, 35200		
GAF Mobile, Baldwin, 36600		
Koppers Co. Woodard, Jefferson, 35189		
Logan Long Co. Tuscaloosa, Tuscaloosa 35401		
Total Plants and Sales x 10^6	4	$4.5
Arkansas		
Bear Brand Roofing Inc. Bearden, Quachita 71720		
Celotex Corp. Camden, Columbia 71701		
Elk Roofing Co. Stephens, Quachita 71746		
Southern Asphalt Roofing Corp. Little Rock, Pulaski 72200		
Total Plants and Sales x 10^6	4	$23
California		
Bird & Son, Inc. San Mateo, San Mateo 94403		
Bird & Son, Inc. Wilmington, Lake 90744		
Celotex Corp. Los Angeles, Los Angeles 90031		
Certain Teed Products Corp. Richmond, Contra Costa 94804		

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
California, (Continued)		
Fibreboard Corp. Martinez, Contra Costa 94553		
Fibreboard Corp. Oakland, Alameda 94600		
Flintkote Co. Los Angeles, Los Angeles 90000		
Flintkote Co. San Andreas, Calaveras 95249		
Johns-Manville Products Los Angeles, Los Angeles 90058 and Pittsburg, Contra Costa		
Lloyd A. Fry Roofing Co. Compton, Los Angeles 90223		
Lloyd A. Fry Roofing Co. San Leandro, Alameda 94577		
Lunday-Thagard Oil Co. South Gate, Los Angeles 90280		
Nicolet Industries Hollister, Santa Cruz 95023		
Owens Corning Fiberglas Santa Clara, Santa Clara 95000		
Rigid Mfg. Co., Inc. Los Angeles, Los Angeles 90022		
Mrs. Paul Smithwick Los Angeles, Los Angeles 90066		
Standard Materials Co., Inc. Merced, Merced 95340		
Thermo Materials, Inc. San Diego, San Diego 92109		
United States Gypsum Co. South Gate, Los Angeles 90280		
Total Plants and Sales x 10^6	20	$70

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Colorado		
Colorado Bitumuls Co. Denver, Denver 80216		
GAF Corp. Denver, Denver 80216		
Lloyd A. Fry Roofing Co. Denver, Denver 80216		
Total Plants and Sales x 10^6	3	$9.5
Connecticut		
Allied Chemical Corp. Mountville, New London 06353		
Tilo Co., Inc. Stratford, Fairfield 06497		
Total Plants and Sales x 10^6	2	$13
Delaware		
Artic Roofings, Inc. Edge Moore, New Castle 19809		
Artic Roofings, Inc. Wilmington, New Castle 19809		
Total Plants and Sales x 10^6	2	$9
Florida		
GAF Corp. Tampa, Hillsborough		
Gardner Martin Asphalt Corp. Tampa, Hillsborough 33605		
Lloyd A. Fry Roofing Co., Inc. Ft. Lauderdale, Broward 33316		

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Florida (Continued)		
Lloyd A. Fry Roofing Co., Inc. Jacksonville, Duval 32206		
Total Plants and Sales x 10^6	4	$7
Georgia		
Certain Teed Products Corp. Port Wentworth, Effingham 91407		
Certain Teed Products Corp. Savannah, Chatham 31402		
GAF Corp. Savannah, Chatham 31402		
Gibson Homans Co. Conyers, Rockdale 30207		
Johns-Manville Products Savannah, Chatham 31402		
Lloyd A. Fry Roofing Co. Atlanta, Fulton 30311		
Mullins Bros. Pvgn. Cntrc. E. Point, Fulton 30044		
Southern Paint Products Atlanta, Fulton 30310		
The Ruberoid Co. Savannah, Chatham 31402		
Total Plants and Sales x 10^6	9	$55
Illinois		
Allied Asphalt Paving Co. Hillside, Cook 60162		
Allied Chemical Corp. Chicago, Cook 60623		

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location

Illinois (Continued)

Amalgamated Roofing Div.
Bedford Park, Cook 60501

Becker Roofing Co. (2 plants)
Chicago, Cook 60647

Bird & Son Inc.
Chicago, Cook 60620

Celotex Co.
Elk Grove Village, Cook 60007

Celotex Co.
Peoria, Peoria 61600

Celotex Co.
Wilmington, Kankakee 60481

Certain Teed Products Corp.
Chicago Heights, Cook 60411

Certain Teed Products Corp.
E. Saint Louis, Saint Clair 62205

Crown Trygg Corp.
Joliet, Will 60434

Flintkote Co.
Chicago Heights, Cook

FS Services, Inc.
Kingston Mines, Peoria 61533

GAF Corp.
Joliet, Will 60433

Globe Industries, Inc.
Chicago, Cook 60600

J. W. Mortell Co. Inc.
Kankakee, Kankakee 60901

Johns-Manville Corp.
Madison, Madison 62060

Johns-Manville Corp.
Waukegan, Lake 60085

Koppers Co.
Chicago, Cook 60000

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Illinois (Continued)		
Lloyd A. Fry Roofing Co. Argo, Cook 60501		
Lloyd A. Fry Roofing Co. Summit, Clay 60501		
Logan Long Co. Chicago, Cook 60638		
McCalman Construction Co. Danville, Vermilion 61832		
Midwest Products Co., Inc. Chicago, Cook 60619		
Nicolet Industries Union, Boone 62635		
Rock Road Construction Co. Chicago, Cook		
Seneca Petroleum Co., Inc. Chicago, Cook 60616		
Triangle Construction Co. Kankakee, Kankakee 60901		
Washington Paint Products Chicago, Cook 60624		
Total Plants and Sales x 10^6	30	$145
Indiana		
Asbestos Mfg. Corp. Michigan City, La Porte 46360		
GAF Corp. Mount Vernon, Posey 47620		
Globe Industries, Inc. Lowell, Lake 46356		
H. B. Reed & Co., Inc. Gary, Lake 46406		

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Indiana (Continued)		
Lloyd A. Fry Brookville, Franklin 47021		
Total Plants and Sales x 10^6	5	\$20
Iowa		
Becker Roofing Co., Inc. Burlington, Des Moines 52601		
Celotex Corp. Dubuque, Dubuque 52001		
Tufcrete Co., Inc. Des Moines, Polk 50309		
Total Plants and Sales x 10^6	3	\$13
Kansas		
Royal Brank Roofing, Inc. Phillipsburg, Phillips 67661		
Total Plants and Sales x 10^6	1	\$4.5
Louisiana		
Bird & Son, Inc. Shreveport, Caddo 71102		
Delta Roofing Mills, Inc. Slidill, Saint Tammann 70458		
Johns-Manville Corp. Marrero, Jefferson 70072		
Slidell Felt Mills, Inc. Slidell, Saint Tammann 70458		
Total Plants and Sales x 10^6	4	\$46

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Maryland		
Congoleum-Nairn, Inc. Finksburg, Carroll 21048		
GAF Corp. Baltimore, Baltimore 21224		
Lloyd A. Fry Roofing Co. Jessup 20794		
Total Plants and Sales x 10^6	3	$22
Massachusetts		
Bird & Son, Inc. Norwood, Norfolk 02062		
Essex Chemical Corp. Peabody, Essex 01960		
GAF Corp. Millis, Norfolk 02054		
Lloyd A. Fry Roofing Co., Inc. Waltham, Middlesex 02154		
Patrick Ross Co. Cambridge, Middlesex 02142		
Total Plants and Sales x 10^6	5	$15
Michigan		
Lloyd A. Fry Roofing Co. Detroit, Wayne 48217		
GAF Corp. Warren, Macomb 48089		
Minnesota		
Duval Mfg. Co., Inc. Minneapolis, Hennepin 55426		

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Minnesota (Continued)		
Duvall Mfg. Co., Inc. Minneapolis, Hennepin 55412		
EDCO Products, Inc. Hopkins, Hennepin 55343		
GAF Corp. Minneapolis, Hennepin 55411		
Lloyd A. Fry Roofing Co. Minneapolis, Hennepin 55412		
B. F. Nelson Mfg. Co., Inc. Minneapolis, Hennepin 55413		
E. J. Pennig Co., Inc. St. Paul, Ramsey 55103		
United States Gypsum Co. St. Paul, Ramsey 55100		
Total Plants and Sales x 10^6	8	$35
Mississippi		
Atlas Roofing Mfg. Co. Meridian, Lauderdale 39301		
Lloyd A. Fry Roofing Co. Hazelwood		
Total Plants and Sales x 10^6	2	$12
Missouri		
Certain Teed Products Corp. Kansas City, Jackson 64126		
GAF Corp. Kansas City, Jackson 64126		
Lloyd A. Fry Roofing Co., Inc. Hazelwood, St. Louis 63042		

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Missouri (Continued)		
Lloyd A. Fry Roofing Co., Inc. N. Kansas City, Clay 64116		
Midwest Pre Cote Co. Kansas City, Clay 64119		
Tamko Asphalt Products, Inc. Joplin, Jasper 64801		
Total Plants and Sales x 10^6	6	$34
New Hampshire		
Tilo Co., Inc. Manchester, Hillsboro 03101		
Total Plants and Sales x 10^6	1	$2
New Jersey		
Atlantic Cement Co. Bayonne, Hudson 07002		
Bird & Son, Inc. Perth Amboy, Middlesex 08862		
Celotex Corp. Edgewater, Middlesex 07020		
Celotex Corp. Perth Amboy, Middlesex 08862		
Flintkote Co., Inc. E. Rutherford, Bergen 07073		
Flintkote Co., Inc. Whippany, Morris 07981		
GAF Corp. South Bound Brook, Somerset 08880		
Johns-Manville Corp. Manville, Somerset 08835		
Karnak Chemical Corp. Clark, Union 07066		

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
New Jersey (Continued)		
Congoleum Nairm, Inc. Kearny, Bergen 07032		
Koppers Co., Inc. Westfield, Union 07090		
Lloyd A. Fry Roofing Co., Inc. Kearny, Bergen 07032		
Middlesex CNC Products Excv. Woodbridge, Middlesex 07095		
Tilo Co., Inc. Westfield, Union 07092		
United States Gypsum Co. Jersey City, Hudson 07300		
Total Plants and Sales x 10^6	15	$52
New Mexico		
Dura Roofing Mfg. Inc. Albuquerque, Bernalillo 87103		
Total Plants and Sales x 10^6	1	$4.5
New York		
Alken-Murry Corp. New York, New York		
Allied Chemical Corp. Binghamton, Broome 13902		
Durok Bldg. Materials Hastings-Hdsn., Westchester 10706		
Tilo Co. Inc. Poughkeepsie, Dutchess 12603		
Tilo Co., Inc. Watertown, Jefferson 13601		
Weatherpanel Sidings, Inc. Buffalo, Erie 14207		
Total Plants and Sales x 10^6	6	$14

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
North Carolina		
Celotex Corp. Goldsboro, Sampson 07530		
Lloyd A. Fry Roofing Co., Inc. Morehead City, Carteret 28557		
Rike Roofing & Mfg. Co. Charlotte, Mecklenburg 28201		
Total Plants and Sales x 10^6	3	$8
Ohio		
Celotex Corp. Cincinnati, Hamilton 45215		
Certain Products Co. Milan, Erie 44846		
Consolidated Paint Varnish Cleveland, Cuyahoga 44114		
Gibson Homans Co., Inc. Cleveland, Cuyahoga 44106		
Johns-Manville Corp. Cleveland, Cuyahoga 44134		
Koppers Co., Inc. Cleveland, Cuyahoga 44106		
Koppers Co., Inc. Youngstown, Mahoning 44500		
Lloyd A. Fry Roofing Co. Medina, Cuyahoga 44256		
Logan Long Co., Inc. Franklin, Warren 45005		
Midwest Products Co., Inc. Cleveland, Cuyahoga 44110		
Overall Paint, Inc. Cleveland, Cuyahoga 44146		
Ranco Industrial Products Cleveland, Cuyahoga 44120		

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Ohio (Continued)		
SET Products, Inc. Cleveland, Cuyahoga 44106		
Tremco Mfg. Co. Cleveland, Cuyahoga 44104		
Total Plants and Sales x 10^6	14	$60
Oklahoma		
Allied Materials Corp. Stroud, Lincoln 74079		
Big Chief Roofing Co., Inc. Ardmore, Carter 73401		
Lloyd A. Fry Roofing Co., Inc. Oklahoma City, Caradian 73117		
Total Plants and Sales x 10^6	3	$12
Oregon		
Bird & Son, Inc. Portland, Multnomah 97200		
Fibreboard Corp. Portland, Multnomah 97210		
Flintkote Co., Inc. Portland, Multnomah 97208		
Herbert Malarkey Roofing Co. Portland, Multnomah 97217		
Lloyd A. Fry Roofing Co., Inc. Portland, Multnomah 97210		
Shell Oil Co. Portland, Multnomah 97210		
Total Plants and Sales x 10^6	6	$16

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Pennsylvania		
Allied Chemical Corp. Philadelphia, Philadelphia 19146		
Celotex Corp. Philadelphia, Philadelphia 19146		
Celotex Corp. Sunbury, Northumberland 17801		
Certain Teed Products Corp. York, York 17303 and St. Gobian, Luzerne, 18707		
ESB Inc. Del. Mertztown, Berks 19539		
GAF Corp. Erie, Erie 16500		
Keystone Roofing Mfg. Co. York, York 17403		
Lloyd A. Fry Roofing Co. Emmaus, Lehigh 18049		
Lloyd A. Fry Roofing Co. York, York 17404		
Monsey Products Co., Inc. Philadelphia, Philadelphia 19128		
H. C. Price Co. Philadelphia, Philadelphia 19115		
Tilo Co., Inc. Philadelphia, Philadelphia 19118		
Total Plants and Sales x 10^6	13	\$63
South Carolina		
Bird & Son, Inc. Charleston Hts., Charleston 29405		
Total Plants and Sales x 10^6	1	\$14

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Tennessee		
Celotex Corp. Memphis, Shelby 38100		
Lloyd A. Fry Roofing Co. Memphis, Shelby 38107		
Total Plants and Sales x 10^6	2	$3
Texas		
American Petrofina Tex. Mt. Pleasant, Titus 75455		
Celotex Corp. Houston, Liberty 77000		
Celotex Corp. San Antonio, Bexar 78200		
Certain Teed Pdts. Corp. Dallas, Dallas 75216		
Daingerfield Mfg. Co. Daingerfield, Morris 75638		
Flintkote Co. Ennis, Ellis 75119		
GAF Corp. Dallas, Dallas		
Gulf States Asphalt Co., Inc. Beaumont, Jefferson 77704		
Johns-Manville Corp. Ft. Worth, Tarrant 76107		
Lloyd A. Fry Roofing Co. Irving, Dallas 75060		
Lloyd A. Fry Roofing Co. Houston, Harris 77029		
Lloyd A. Fry Roofing Co. Lubbock, Lubbock 79408		

Table A-1(Continued). LISTING OF ASPHALT ROOFING PLANTS IN 1973

SIC 2952

Company Name and Location		
Texas (Continued)		
Ruberoid Co. Dallas, Dallas 75222		
Southwestern Petroleum Fort Worth, Tarrant 76106		
Texas Sash & Door Ft. Worth, Tarrant 76101		
Total Plants and Sales x 10^6	15	$84
Utah		
Lloyd A. Fry Roofing Co. Woods Cross, Davis 84087		
Total Plants and Sales x 10^6	1	$1.5
Washington		
Certain Teed Products Corp. Tacoma, Pierce 98421		
Kollogg Co.,Inc. Washington		
B. F. Nelson Mfg. Co. Inc. Washington		
Total Plants and Sales x 10^6	3	$5
West Virginia		
Celotex Corp. Chester, Hancock 26034		
Total Plants and Sales x 10^6	1	
Total United States Plants and Sales x 10^6	202	$881

APPENDIX B. EMISSION TEST PROCEDURES AND RESULTS

INTRODUCTION

To obtain quantitative emission data, tests were conducted at three plants. The following tests were made:

> Plant A - Particulate, PPOM, and gaseous emissions from felt saturators running 27- and 55-pound felt. Tests were made with and without a HEAF collector in the vent stream.
>
> Plant B - Particulate, PPOM, and gaseous emission from a felt saturator running 27- and 55-pound felt, and from an asphalt blowing operation. Tests were made simultaneously before and after process heaters used as fume incinerators on each process.
>
> Plant C - Particulate, PPOM, and gaseous emissions from an asphalt blowing operation. Tests were made simultaneously before and after a process heater used as a fume incinerator.

This appendix describes the test procedures used, and the raw data used to calculate the emissions summarized in this report.

TEST PROCEDURES

Emission testing procedures followed those described in EPA methods 1 through 5.[B.1] Method 1 was used to locate sampling sites. The selected sites, which were at times not ideal, are shown in Figures B-1 through B-9 along with the number of sampling points utilized at each site.

Particulate

Particulate matter was sampled isokinetically by using the sampling trains illustrated in Figures B-10 and B-11.

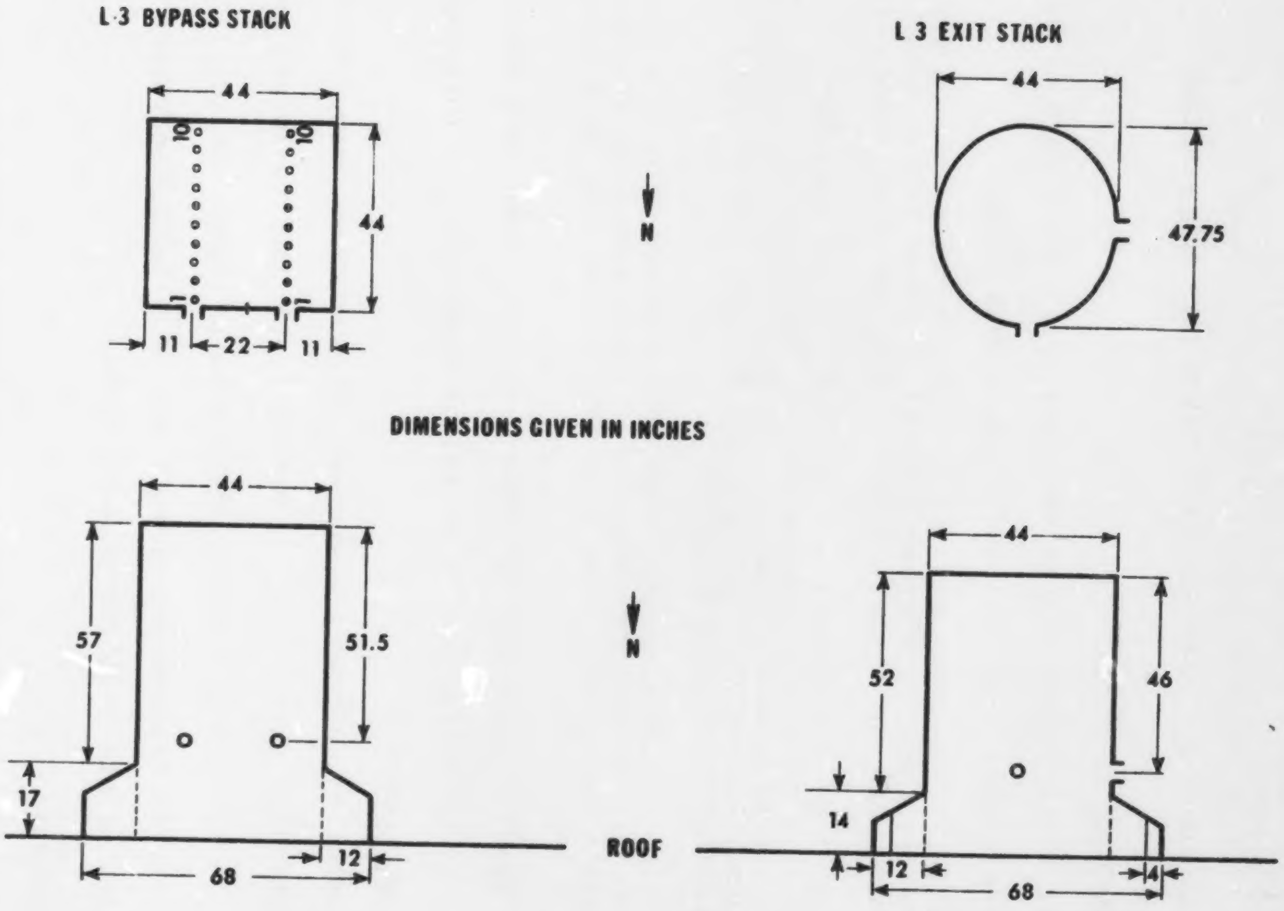

L-3 BYPASS STACK
L 3 EXIT STACK
44
44
10
10
11
22
11
N
44
47.75
DIMENSIONS GIVEN IN INCHES
44
57
51.5
17
12
68
N
ROOF
44
52
46
14
12
4
68

Figure B-1. Line L-3 saturator bypass and exit stack - Plant A.

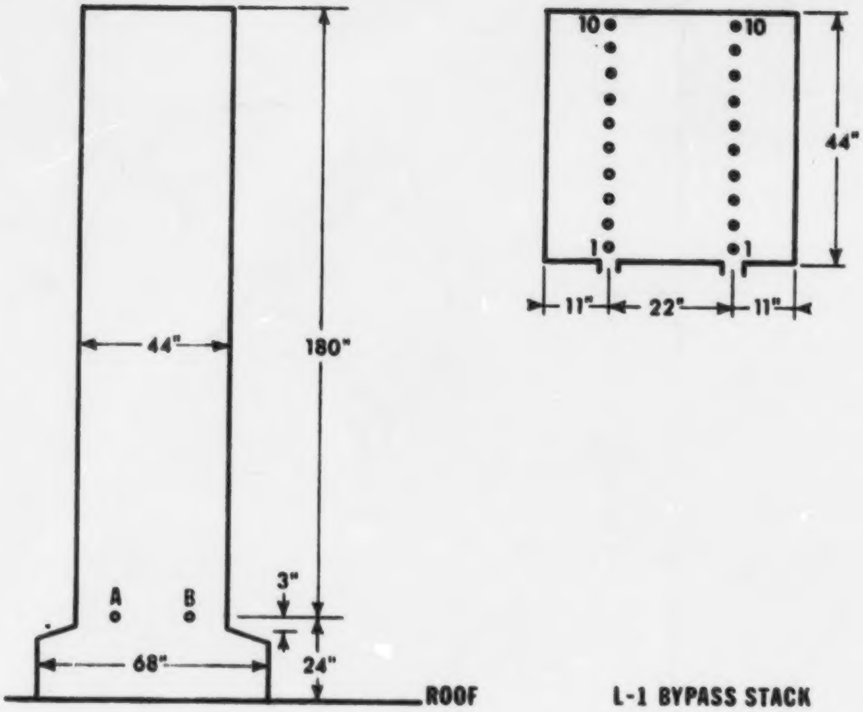
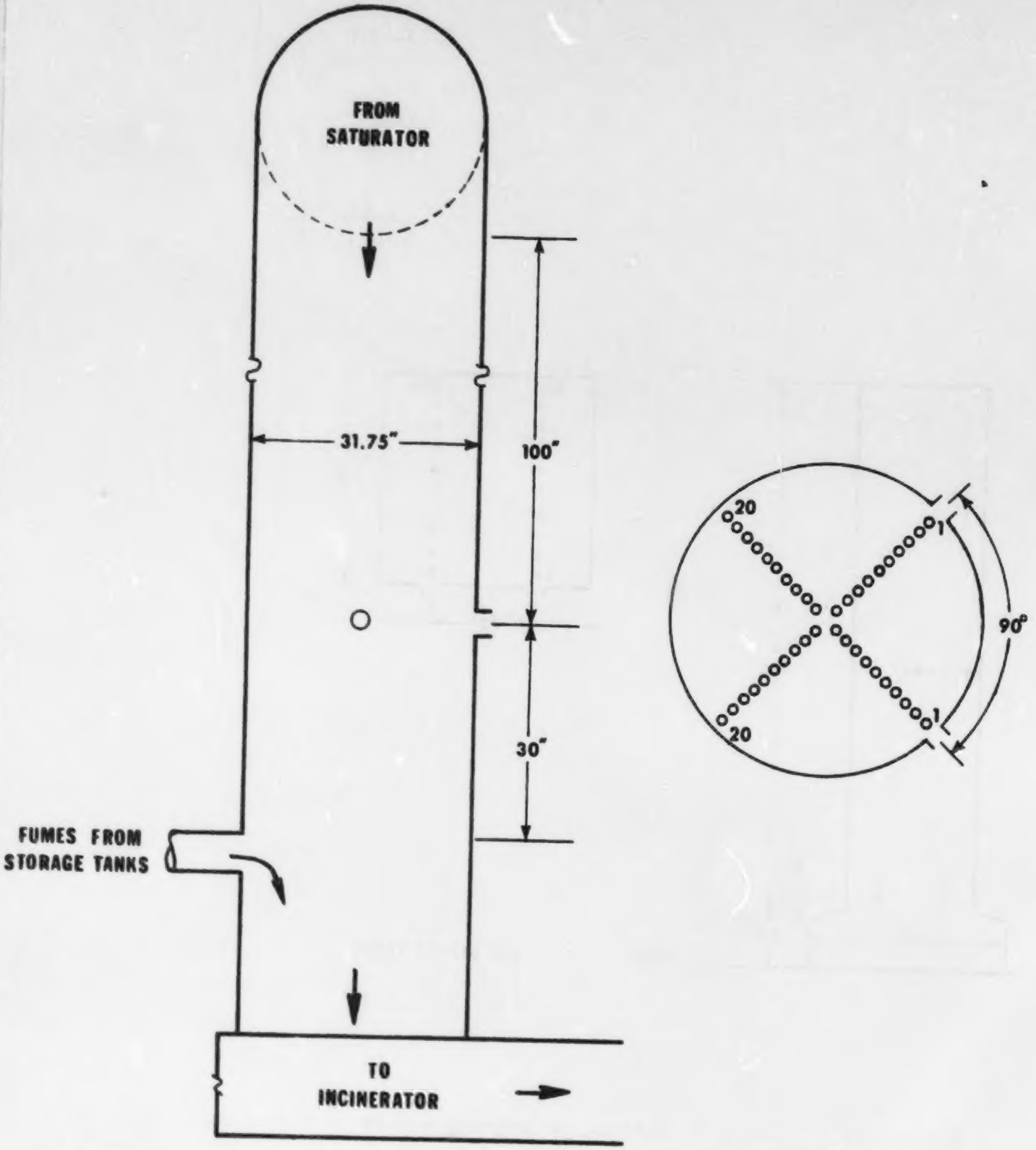

10
10
44"
1
1
11"
22"
11"
44"
180"
A
B
3"
68"
24"
ROOF
L-1 BYPASS STACK

Figure B-2. Line 1 saturator bypass stack - Plant A.



FROM SATURATOR
31.75"
100"
30"
FUMES FROM STORAGE TANKS
TO INCINERATOR
20
1
20
1
90°

Figure B-3. Asphalt blowing inlet - Plant B.

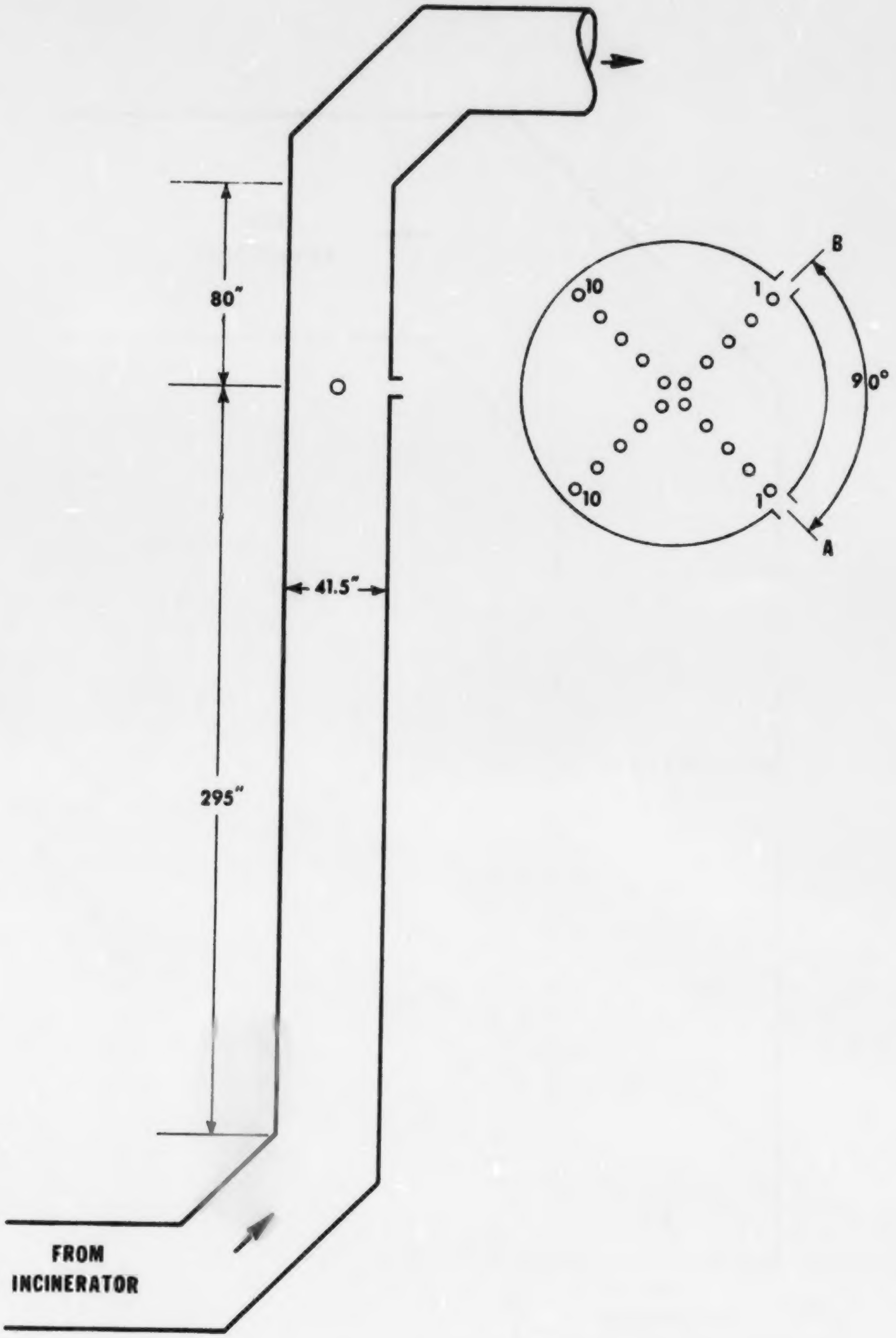

80"
295"
41.5"
FROM INCINERATOR
B
A
90°
1
10
1
10

Figure B-4. Asphalt blowing outlet - Plant B.

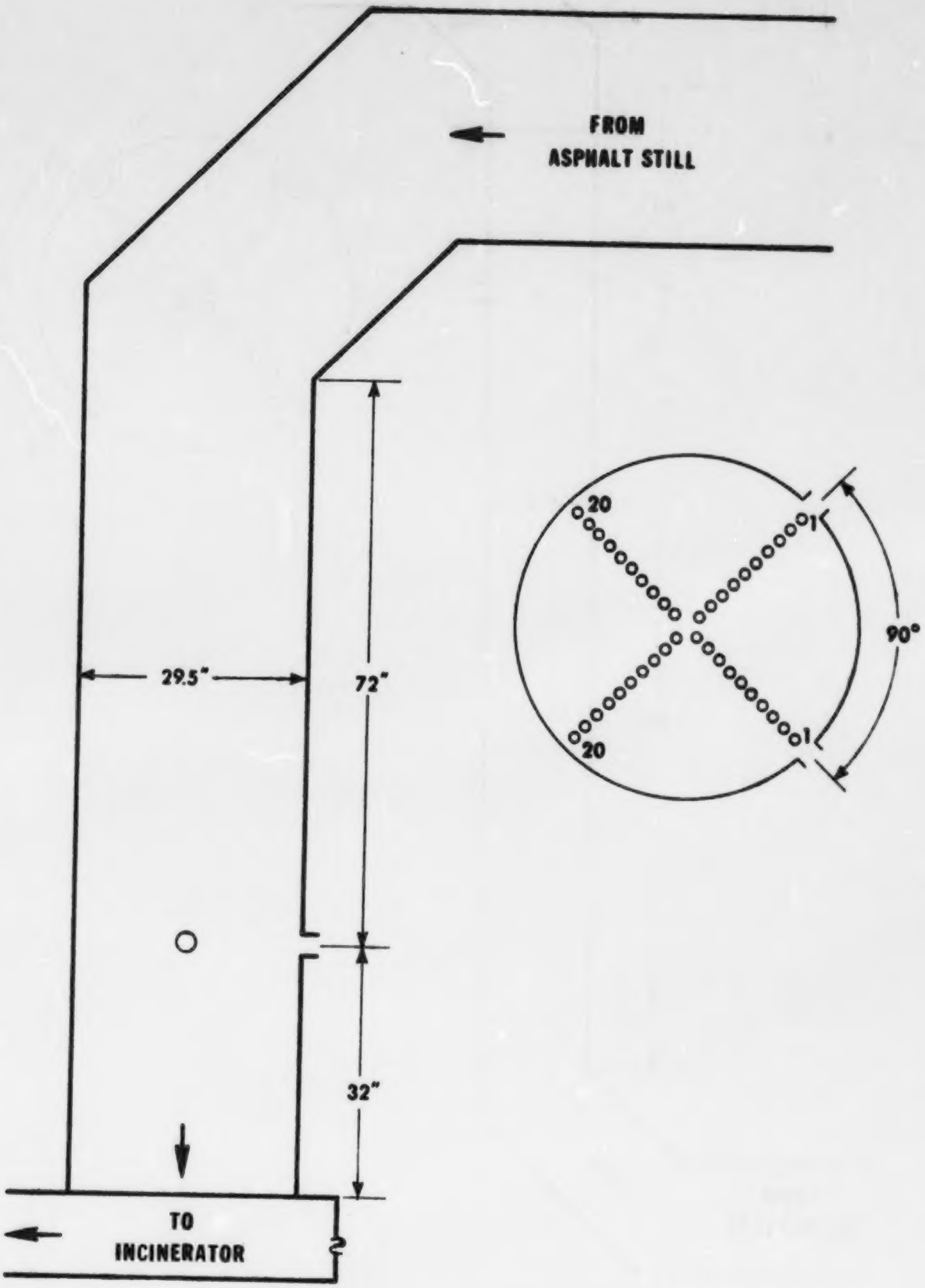

FROM
ASPHALT STILL
29.5"
72"
32"
20
1
20
1
90°
TO
INCINERATOR

Figure B-5. Saturator inlet - Plant B.

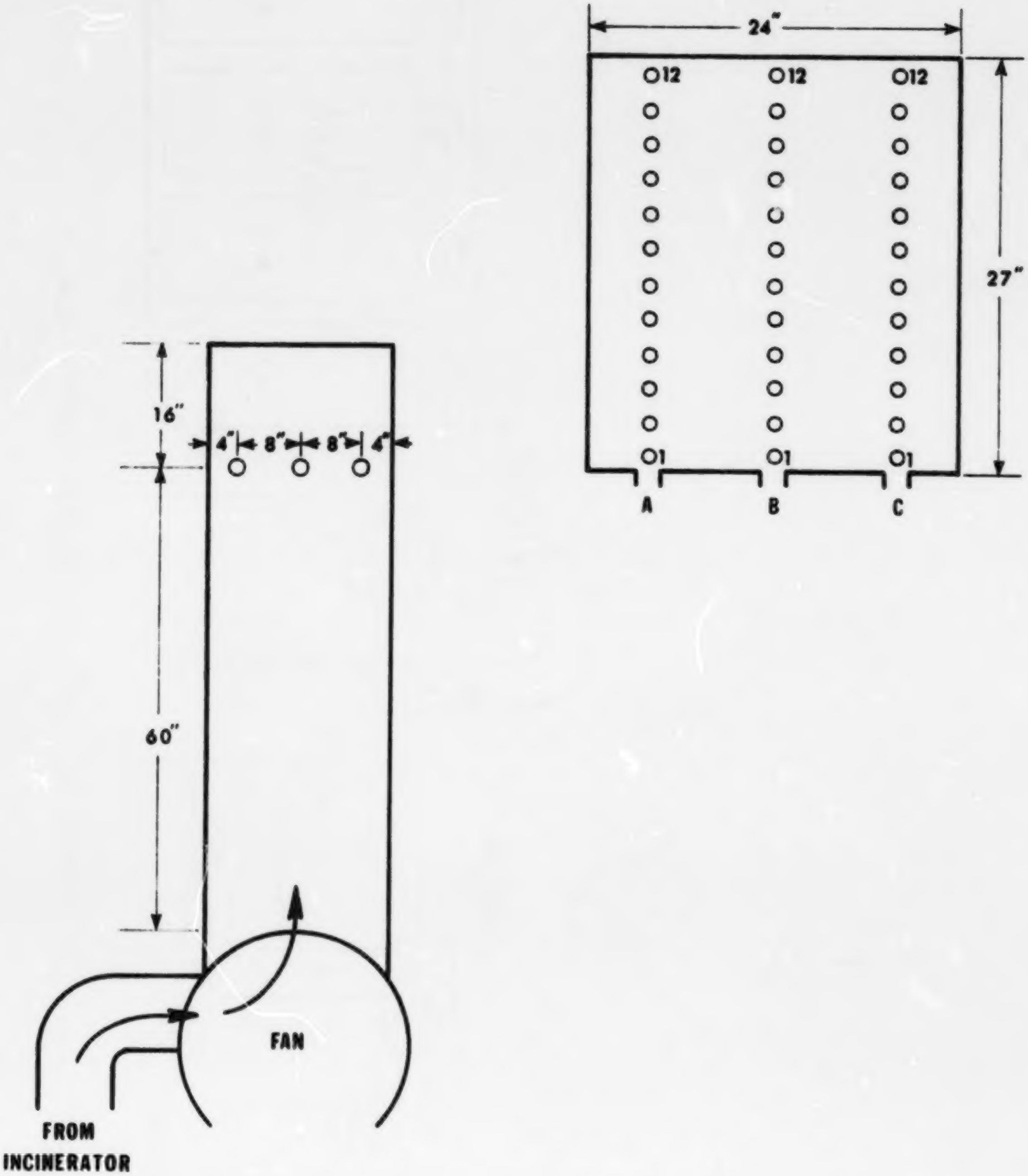

24"
12
12
12
27"
1
1
1
A
B
C
16"
4"
8"
8"
4"
60"
FAN
FROM INCINERATOR

Figure B-6. Saturator outlet - Plant B.

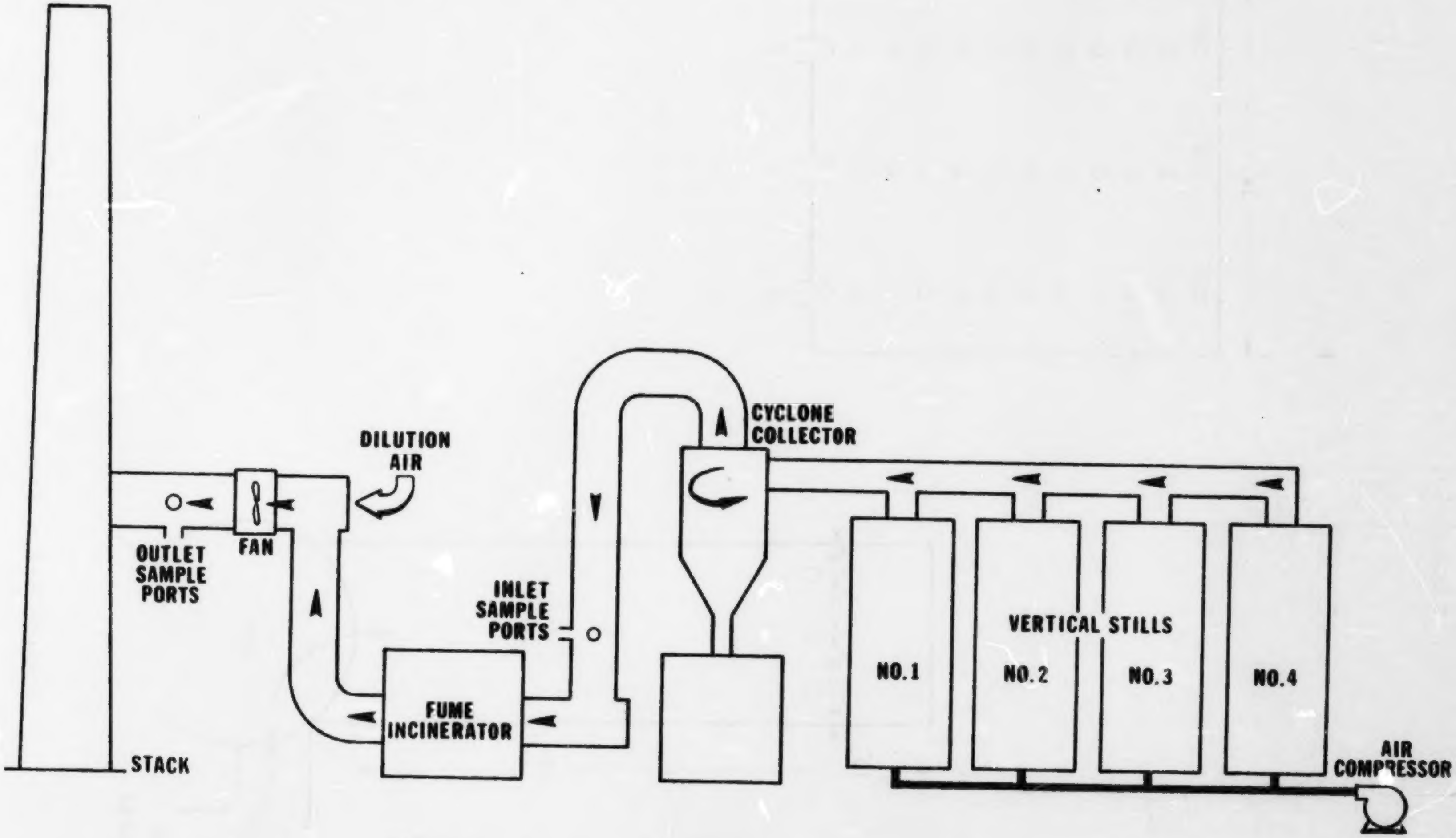

STACK
OUTLET SAMPLE PORTS
FAN
DILUTION AIR
FUME INCINERATOR
INLET SAMPLE PORTS
CYCLONE COLLECTOR
VERTICAL STILLS
NO.1
NO.2
NO.3
NO.4
AIR COMPRESSOR

Figure B-7. Air blowing operation - Plant C.

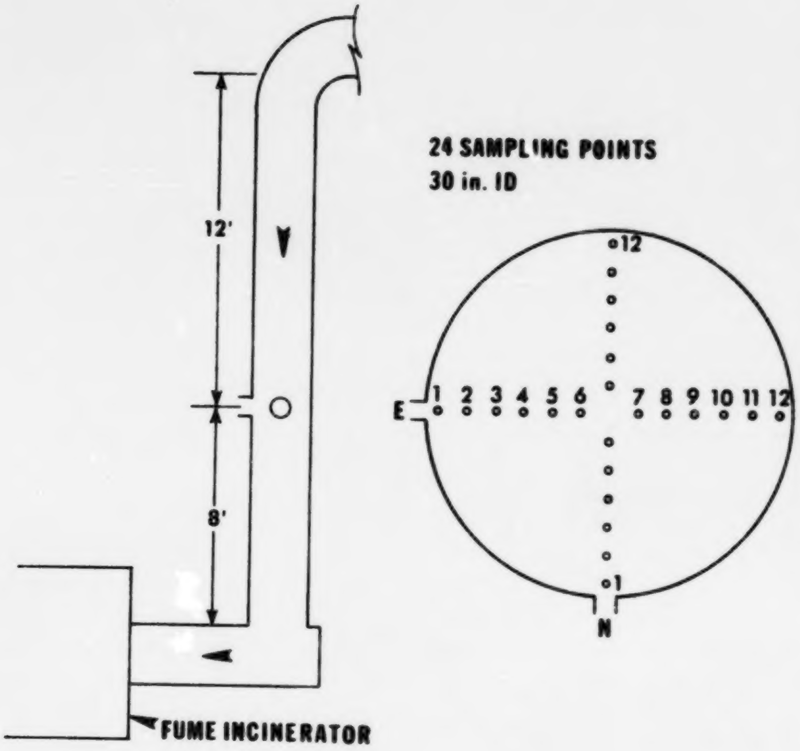

24 SAMPLING POINTS
30 in. ID
12'
8'
E
N
1
2
3
4
5
6
7
8
9
10
11
12
FUME INCINERATOR

Figure B-8. Asphalt blowing inlet - Plant C.

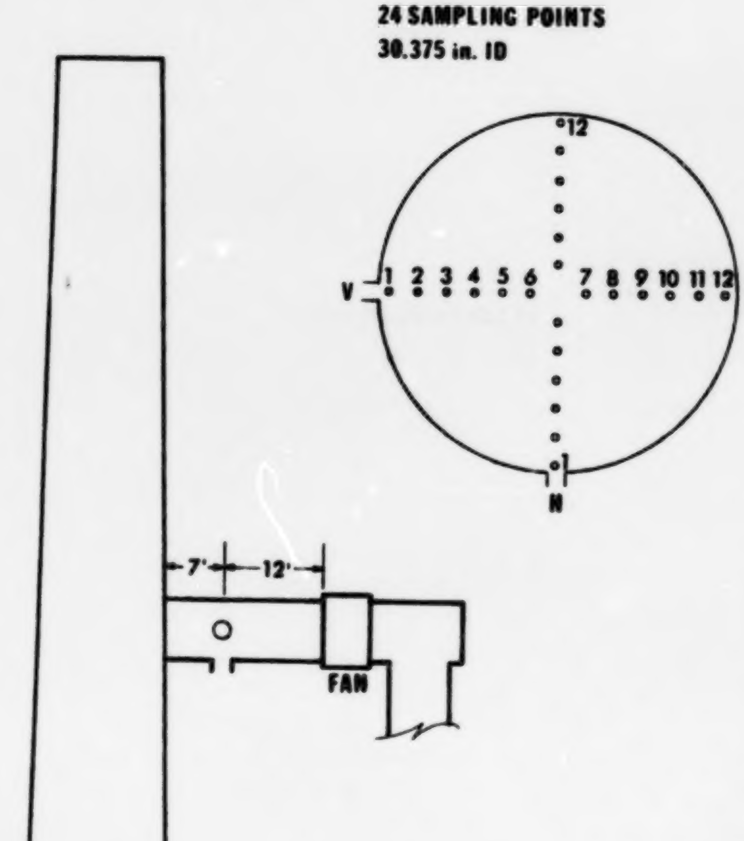

24 SAMPLING POINTS
30.375 in. ID
12
V
1 2 3 4 5 6 7 8 9 10 11 12
N
7'
12'
FAN
STACK

Figure B-9. Asphalt blowing outlet - Plant C.

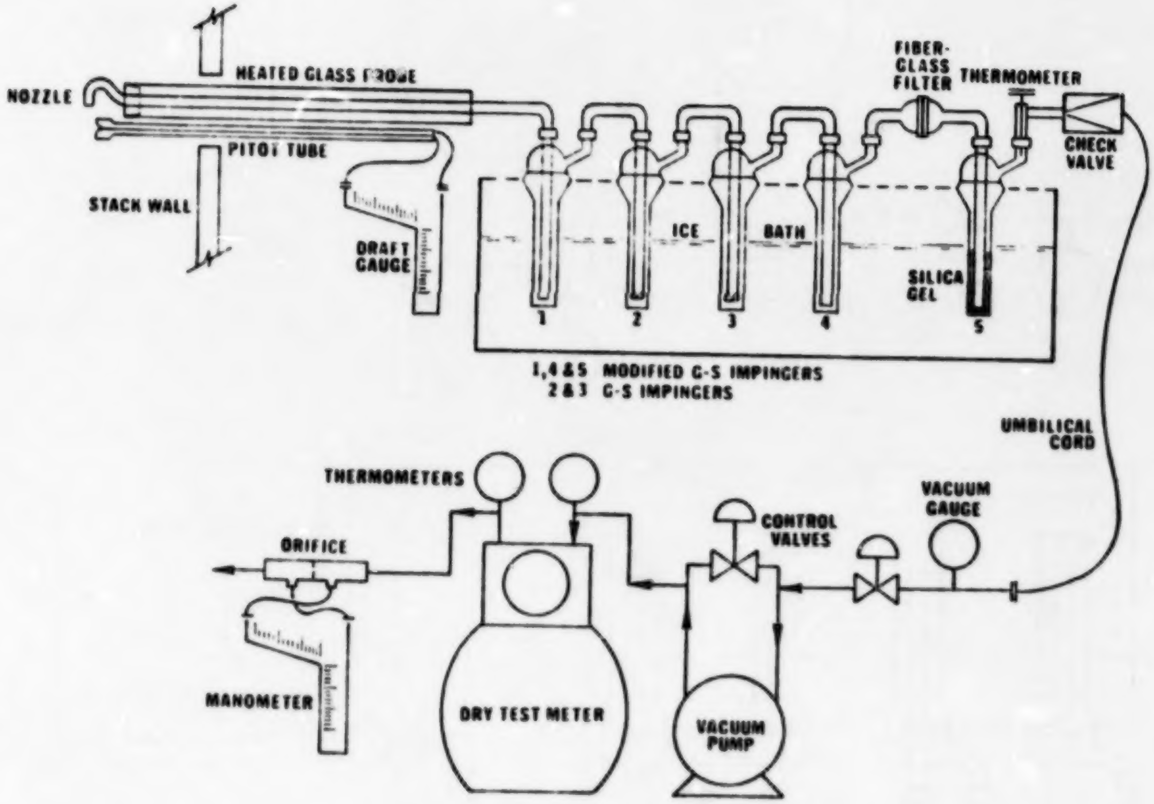

NOZZLE
HEATED GLASS PROBE
PITOT TUBE
STACK WALL
DRAFT GAUGE
FIBER-GLASS FILTER
THERMOMETER
CHECK VALVE
ICE
BATH
SILICA GEL
1
2
3
4
5
1,4&5 MODIFIED G-S IMPINGERS
2&3 G-S IMPINGERS
UMBILICAL CORD
VACUUM GAUGE
CONTROL VALVES
THERMOMETERS
ORIFICE
MANOMETER
DRY TEST METER
VACUUM PUMP

Figure B-10. Sampling Train for particulate in uncontrolled streams.

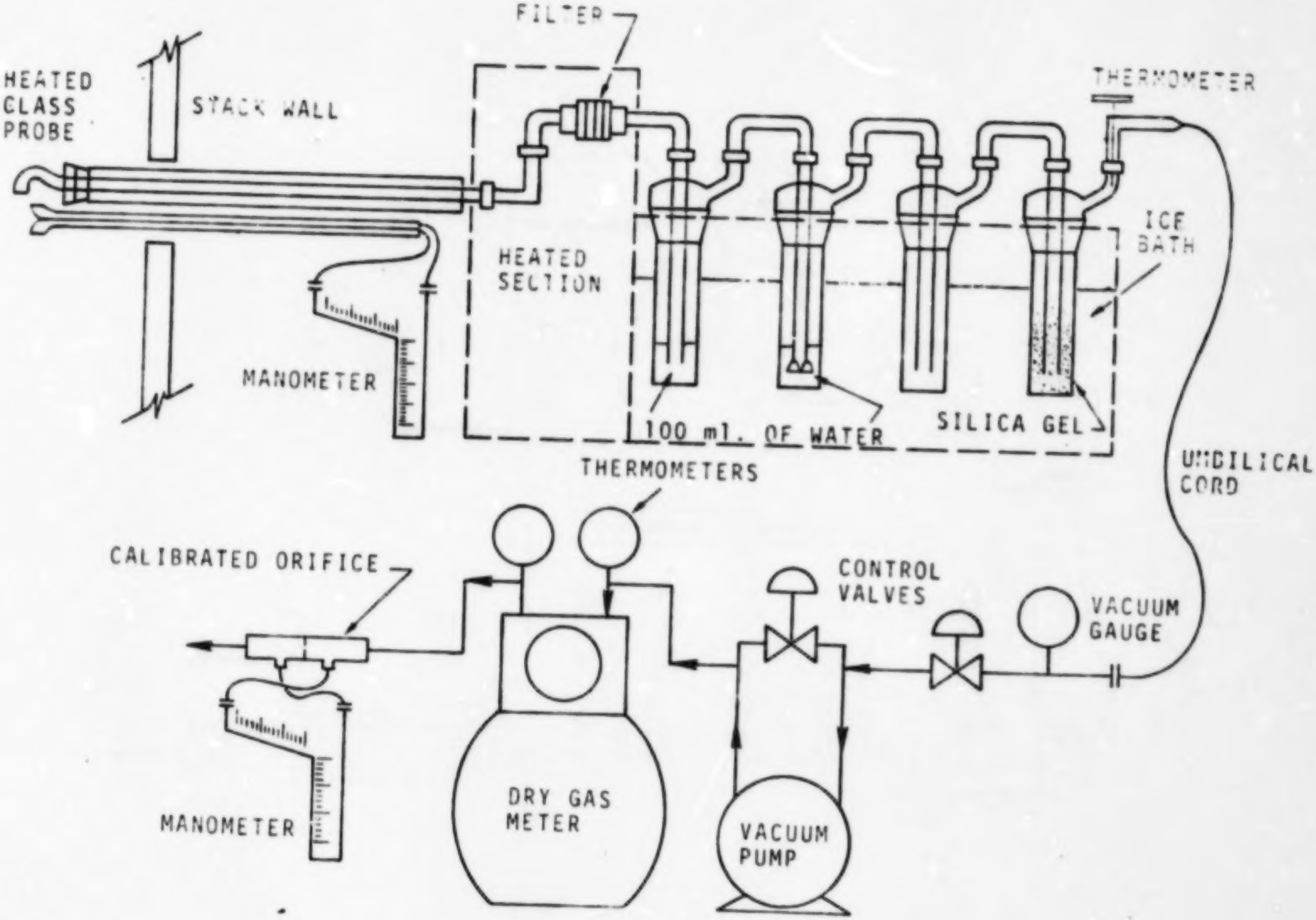

FILTER
HEATED
GLASS
PROBE
STACK WALL
THERMOMETER
HEATED
SECTION
ICE
BATH
MANOMETER
100 ml. OF WATER
SILICA GEL
UMBILICAL
CORD
THERMOMETERS
CALIBRATED ORIFICE
CONTROL
VALVES
VACUUM
GAUGE
DRY GAS
METER
VACUUM
PUMP
MANOMETER

Figure B-11. Particulate sampling train used in controlled streams.

For uncontrolled emission streams, the sampling train in Figure B-10 was used. With this train, the organic particulate was condensed in the impingers which contained water (Impingers 1, 2 and 3). The final filter was used as a back-up to ensure complete particulate collection. After sampling, the filter was removed and placed into a container for transfer to the laboratory. The impinger contents were measured and placed in glass containers for later analysis, and the entire sampling train was rinsed with acetone and methylene chloride. These rinsings were placed into a third container for later analysis.

For gas streams with relatively low particulate concentrations as found after a control device the EPA Method 5 sampling train as shown in Figure B-11 was used. Sample recovery in this case yielded: 1) an acetone and methylene chloride rinse of the probe and front half of the filter holder, 2) the filter, 3) the impinger contents, and 4) an acetone and methylene chloride rinse of the impingers and connecting glassware. The filterable particulate was considered to be that portion caught in the probe and on the filter. Analysis consisted of drying the acetone/methylene chloride fraction in a tared beaker at room temperature and weighing the residue. The filters were desiccated and weighed. The impinger solutions were extracted with ether and chloroform in a separatory funnel. This extract was placed in tared beakers and dried at room temperature and weighed. The remaining impinger solution was boiled to dryness and weighed. Total particulate was the sum of these individual fractions.

When using the EPA Method 5 train considerable seepage of liquid organic matter through the filter occurred, and a true breakdown between filterable and non-filterable or condensible particulate could not be made. Also, in all cases, drying of the collected particulate residues was a problem since the samples continually lost weight in a desiccator. This was due to loss of the lighter organic portions of the sample. To prevent undue sample loss, all final sample weights were recorded after 48 hours in a desiccator.

Polycyclic Particulate Organic Matter

Previous studies on the collection of these compounds have shown the necessity for cooling the sample to at least 65° F. before all PPOM compounds can be collected.[B.2,B.3] This was accomplished by utilizing the particulate sampling train shown in Figure B-10. With the impingers contained in an ice-water bath, the final filter was maintained at less than 65°F. PPOM collection was accomplished by isokinetically traversing the ducts as required for particulate sampling. Sample recovery consisted of three fractions: namely, the filter, the impinger contents, and an acetone and methylene chloride rinse of the entire train interior, up to the final filter. The samples were kept in dark glass containers and refrigerated during storage.

PPOM analysis consisted of the following steps:[B.4]

> The used filters were soxhlet extracted for 30 hours with methylene chloride, and the aqueous impinger solutions were extracted four times with methylene chloride.

These extracts were combined and reduced to a small volume on a rotary evaporator, at which stage the acetone and methylene chloride rinses supplied were added to the evaporator and the whole reduced in volume. When no further solvent could be removed, the volume remaining was approximately 20 ml of black oily liquid. One ml of this solution was subjected to quantitative liquid chromatography on an alumina column. Following elution of the aliphatic hydrocarbons with 25 ml of petroleum ether, the sample was eluted with 50 mls of 10% methylene chloride in petroleum ether. This latter fraction would contain the compounds of interest that were present. This sample was evaporated with a stream of nitrogen to a volume of about 25 μl for further analyses.

The sample was then analyzed by gas chromatographic-mass spectrometry using chemical ionization with methane. The chromatographic separation was accomplished using 6 to 18 foot long, 2.5% Dexil 300 columns programmed from 240° to 300° C at 1°C per min. A Varian 1700 chromatograph was interfaced with a Finnigan 1015 quadruple mass spectrometer equipped with a System Industries 1500 data acquisition system. The total ion chromatogram was displayed on the CRT unit. Individual ion chromatograms for the nominal masses of the protonated molecular ions of the compounds of interest were overlayed with this chromatogram to locate the desired polynuclear aromatic compounds. Benzpyrenes were quantitated by this layer chromatography and spectrofluorescence.

The detection limit for this procedure is on the order of 3 nanograms, and the accuracy for well defined peaks is ± 10%.

ALDEHYDES

Aldehydes were collected in a solution of MBTH (3-methyl-2-benzothiazolone hydrazone hydrochloride) contained in 2-liter flasks.[B.5] Samples were collected by following procedures described in EPA Method 7.[B.1] Analysis was performed colorimetrically.

HYDROGEN SULFIDE

These compounds were collected in a solution of cadmium sulfate and hydroxide contained in a set of midget impingers: The resulting concentration was determined colorimetrically.[B.6]

Gaseous Hydrocarbons and Carbon Monoxide

These compounds were collected in Tedlar[R] plastic bags and analyzed with a flame ionization detector calibrated with a methane/air mixture. CO was catalytically converted to CH_4 in the presence of hydrogen and analyzed as CH_4.

TEST RESULTS

Tables B-1 through B-21 contain the field data and analytical results obtained during the studies. These data were summarized in the body of this report.

[R] Registered Trademark

REFERENCES FOR APPENDIX B

B.1 Federal Register, Vol. 36, No. 247, Part II, December 23, 1971.

B.2 Stenburg, R. L., et al., Sample Collection Techniques for Combustion Source-Benzopyrene Determination. Industrial Hygiene Journal. August 1961.

B.3 Diehl, E. K., et al., Polynuclear Hydrocarbon Emission from Coal-Fired Installations. ASME Paper 66-Pw-2. J. of Engineering for Power, 1966.

B.4 Jones, P.W. and P.E. Strop, Analysis of Carcinogenic PNA's from Asphalt Roofing Industry. Battelle Columbus Laboratories, March 11, 1974, May 30, 1974 and July 18, 1974.

B.5 Selected Methods for the Measurement of Air Pollutants. U.S. Department of Health, Education and Welfare, May 1965. Publication 99-AP-11.

B.6 Jacobs, M.B., et al., Analytical Chemistry, 29 (9), September 1957.

Table B-1 SUMMARY OF PROCESS DATA FOR NUMBER 3 ROLL ROOFING MACHINE - PLANT A

Date	3/26/74	3/27/74	3/28/74
Test No.	BP3-1&2	L3-1&2	BP3-3&4 L3-3&4
Felt weight[a]	27	27	27
Felt width, inches	36	36	36
Felt moisture, %	3.5	3.7	3.4
Felt speed, fpm	350-400[b]	350-400[b]	350-400[b]
Felt, tons/hr	1.85	1.77	1.80
Saturant temperature, °F	427	426	431
Softening point, °F	105-115	105-115	105-115
Saturant, tons/hr	2.66	2.52	2.60
Total process wt., tons/hr	4.51	4.29	4.40
HEAF Control Device		New Design	
Filter media speed, ft^2/hr	48.5	48.5	48.5
Pressure drop across HEAF and demister, inches H_2O	20.5	20.5	20.5

---

a) Pounds per 480 sq. ft.

b) Felt rate determined by plant personnel

Table B-2 SUMMARY OF PROCESS DATA FOR NUMBER 1 SHINGLE MACHINE - PLANT A

Date	3/26/74	3/27/74
Test No.	L1-1 to 4	BP1-1 to 4
Felt weight[a]	55	55
Felt width, inches	48	48
Felt moisture, %	3.4	3.1
Felt speed, fpm	350-440[b]	
Felt, tons/hr	5.69	5.78
Saturant temperature, °F	435	435
Softening point, °F	120-130	120-130
Saturant, tons/hr	10.25	10.25
Total process wt., tons/hr	15.94	16.03
HEAF Control Device	New Design	
Filter media speed, ft^2/hr	47.1	47.1
Pressure drop across HEAF and demister, inches of H_2O	27.0	27.0

---

a) Pounds per 480 sq. ft.
b) Felt rate determined by plant personnel

Table B-3 DATA SUMMARY FOR ASPHALT SATURATOR - PLANT A, Line 3 (27 lb. felt)

Run Number	BP3-1	BP3-2	BP3-4	BP3-3	L3-1	L3-2	L3-4	L3-3
		Uncontrolled				Controlled		
Date, 1974	3/26	3/26	3/28	3/28	3/27	3/27	3/28	3/28
Volume of Gas Sampled - DSCF[a]	79.936	80.184	83.435	77.428	102.284	107.214	104.515	102.776
Average Stack Temperature - °F	140	140	130	131	154	146	135	135
Percent Moisture by Volume - %	0.83	1.08	1.44	0.90	1.12	1.16	1.07	1.00
Stack Volumetric Flow Rate - DSCFM[b]	33,605	34,018	33,114	32,834	29,012	30,316	30,533	29,436
Stack Volumetric Flow Rate - ACFM[c]	33,886	34,388	33,598	33,133	29,341	30,673	30,862	29,734
Percent Isokinetic	95.6	94.8	101.3	102.9	99.4	99.8	96.6	98.5
Particulate - Filterable Catch								
milligrams	-	-	-		11.3	24.8	8.6	
gr/DSCF[d]	-	-	-		.00170	.00356	.00126	
gr/ACF	-	-	-		.00144	.00305	.00109	
lb/hr	-	-	-		.423	.927	.332	
lb/ton of felt	-	-	-	PPOM TEST	0.24	0.52	0.18	PPOM TEST
Particulate - Total								
milligrams	1206.3	629.0	291.9		139.2	109.7	145.5	
gr/DSCF	.233	.121	.0540		.021	0.0158	0.0215	
gr/ACF	.200	.104	.047		.0177	0.0135	0.0185	
lb/hr	67.1	35.3	15.3		5.22	4.10	5.62	
lb/ton of felt	36.3	19.1	8.51		2.95 1.22	2.31 0.96	3.12 1.28	

a) Dry standard cubic feet at 70°F, 29.92 in Hg.
b) Dry standard cubic feet per minute at 70°F, 29.92 in Hg.
c) Actual cubic feet per minute.
d) Grains per dry standard cubic foot.

Table B-4 DATA SUMMARY FOR ASPHALT SATURATOR - PLANT A, Line 1 (55 lb. felt)

Run Number	BP1-1	BP1-2	BP1-4	BP1-3	L1-1	L1-2	L1-4	L1-3
		Uncontrolled				Controlled		
Date, 1974	3/27	3/27	3/27	3/27	3/26	3/26	3/26	3/26
Volume of Gas Sampled - DSCF[a]	2.713	89.050	93.792	91.964	82.678	84.982	69.230	82.879
Average Stack Temperature - °F	165	158	171	176	178	180	174	174
Percent Moisture by Volume - %	2.4	1.08	1.02	1.75	1.18	1.05	1.40	1.02
Stack Volumetric Flow Rate - DSCFM[b]	29,806	29,825	30,394	29,184	30,415	31,139	26,591	29,950
Stack Volumetric Flow Rate - ACFM[c]	30,539	30,151	30,707	29,704	30,777	31,471	26,970	30,260
Percent Isokinetic		98.1	101.4	103.5	99.9	100.3	95.7	101.7
Particulate - Filterable Catch								
milligrams	-	-	-		17.2	16.7	76.2	
gr/DSCF[d]	-	-	-		.00321	.00303	.01698	
gr/ACF	-	-	-		.00258	.00244	.01378	
lb/hr	-	-	-		0.836	0.809	3.871	
lb/ton of felt	-	-	-	PPOM TEST	0.15	0.14	0.68	PPOM TEST
Particulate - Total								
milligrams	48.4[e]	1845.1	824.7		366.1	439.8	302.2	
gr/DSCF	0.275	0.32	0.136		0.068	0.080	0.067	
gr/ACF	0.223	0.26	0.112		0.055	0.064	0.055	
lb/hr	68.7	81.7	35.4		17.8	21.3	15.3	
lb/ton of felt	12.1	14.1	6.11		3.1	3.8	2.7	

a) Dry standard cubic feet at 70°F, 29.92 in Hg.
b) Dry standard cubic feet per minute at 70°F, 29.92 in Hg.
c) Actual cubic feet per minute.
d) Grains per dry standard cubic foot.
e) Based on data obtained during particle sizing run

Table B-5 PPOM EMISSIONS-SATURATOR - PLANT A

(Net weight in sample, micrograms)

Compound	Test L1-3 3/26/74	Test BP1-3 3/27/74	Test L3-3 3/28/74	Test BP3-3 3/28/74
Benz(c)phenanthrene	0.78	1.3	0.075	0.15
7,12-Dimethylbenz (a)anthracene	0.23	0.91	0.065	0.065
Benz(e)pyrene	0.58	0.88	0.035	0.05
Benz(a)pyrene	0.12	0.66	0.130	0.20
3-Methylcholanthrene	0	1.00	0.070	0.115
Dibenz(a,h)pyrene	0.06	0.50	0	0
Dibenz(a,i)pyrene	0	0.50	0	0

NOTE: BP test numbers designate uncontrolled emissions.

Table B-6 GASEOUS EMISSION DATA
ASPHALT SATURATOR - PLANT A

Compound	Uncontrolled	Controlled
	Line 1	
HC[a]	58 ppm	79 ppm
CO	614	410
CHOH[b]	2.39 4.80	2.46 0.69
	Line 3	
HC[a]	43 ppm	71 ppm
CO	512	466
CHOH[b]	3.3 2.9	2.5 2.2

a) Total gaseous hydrocarbons expressed as CH_4.
b) Total aldehydes expressed as formaldehyde.

NOTE: H_2S not detectable in any sample.

Plant B

Table B-7 PROCESS DATA FOR FELT SATURATOR-ROLL ROOFING

Test No.	1 & 2	3 & 4 (PPOM)	5 & 6
Felt			
Felt Weight[a]	27	27	27
Felt Width, inches	36	36	36
Felt moisture, %	7	7	7
Felt speed, fpm	251	326	340
Felt rates, tons/hr	1.27	1.65	1.72
Saturant temp., °F	450	455	448
Softening point, °F	130-150	130-150	130-150
Saturant, tons/hr	1.90	2.47	2.58
Total process wt., tons/hr	3.17	4.12	4.3
Afterburner Control Device			
Fuel rate	71 gal/hr of #2 fuel oil = 10.3 X 10^6 BTU/hr		
Inlet temp., °F	175	175	175
Outlet temp., °F	1200	1200	1150

a) Pounds per 480 sq. ft.

Plant B

Table B-8 PROCESS DATA FOR FELT SATURATOR-SHINGLE LINE

Test No.	9 & 10	11 & 12	13 & 14 (PPOM)
Felt			
Felt Weight[a]	51.5	51.5	51.5
Felt Width, inches	48	48	48
Felt moisture, %	6.5	6.5	6.5
Felt speed, fpm	277	317	180
Felt, tons/hr	5.35	6.12	3.48
Saturant temp., °F	440	445	460
Softening point, °F	130-150	130-150	130-150
Saturant, tons/hr	8.83	10.10	5.24
Total process wt., tons/hr	14.18	16.22	9.22
Afterburner Control Device			
Fuel rate	71 gal/hr #2 fuel oil - 10.3×10^6 BTU/hr		
Inlet temp., °F	175	175	175
Outlet temp., °F	1100	1250	1200-550

a) Pounds per 480 sq. ft.

Table B-9 PROCESS DATA FOR ASPHALT BLOWING - PLANT B

Plant B

Location

Date May 10 & 14, 1974

Observer DeWees

Test No.	7 & 8	15 & 16	17 & 18
Still No.	1	1	1
Quantity of Asphalt, gallons			
Charged	17,920	17,920	17,920
After Blowing	-	-	-
Still Temp. °F			
Middle	450-490	450-480	450-490
Air Blowing Pressure, psig	9	9	9
Blowing Time, minutes	291	254	45
Product Asphalt			
Melt Point, °F	247	223	132
Afterburner			
Fuel Rate, #2 oil gal/hr	53	53	53
Inlet Temp. °F	300	325	270
Outlet Temp. °F	1000	1000	1000

Table B-10. DATA SUMMARY FOR ASPHALT SATURATOR - PLANT B

Run Number	Uncontrolled				Controlled			
	1	5	9	11	2	6	10	12
Date, 1974	5/7	5/8	5/13	5/13	5/7	5/8	5/13	5/13
Volume of Gas Sampled - DSCF[a]	89.670	100.12	103.878	77.353	92.110	98.298	89.032	87.365
Average Stack Temperature - °F	187	198	141	153	546	541	555	950
Percent Moisture by Volume - %	1.4	1.6	3.8	3.5	3.1	3.4	1.7	3.0
Stack Volumetric Flow Rate - DSCFM[b]	9905	10,761	10,769	8317	16,114	17,040	16,932	13,684
Stack Volumetric Flow Rate - ACFM[c]	12,272	13,525	12,700	9962	31,504	33,139	32.913	37,478
Percent Isokinetic	991	101.8	98.7	101.8	105.0	107.9	98.3	119.4
Particulate - Filterable Catch								
milligrams					153.8	185.2	359.5	101.4
gr/DSCF					0.0262	0.0291	0.0623	0.0179
gr/ACF					0.0134	0.0150	0.0321	0.0065
lb/hr					3.62	4.25	9.04	2.10
Particulate - Total								
milligrams	2626.6	2219.6	1854.4	2384.7	695.0	637.3	703.9	450.1
gr/DSCF	0.452	0.342	0.295	0.478	0.119	0.100	0.122	0.0795
gr/ACF	0.365	0.272	0.250	0.397	0.0607	0.0514	0.0628	0.0290
lb/hr	33.4	31.6	27.2	33.9	16.4	14.6	17.7	9.3

Table B-11. DATA SUMMARY FOR ASPHALT SATURATOR - PPOM TESTS PLANT B

Run Number	Uncontrolled		Controlled	
	3	13	4	14
Date, 1974	5/8	5/13	5/8	5/13
Volume of Gas Sampled - DSCF[a]	93.491	86.895	99.907	98.736
Average Stack Temperature - °F	168	162	535	553
Percent Moisture by Volume - %	1.5	3.3	2.9	4.9
Stack Volumetric Flow Rate - DSCFM[b]	10,266	9206	18,006	16,041
Stack Volumetric Flow Rate - ACFM[c]	12,305	11,183	34,604	32,180
Percent Isokinetic	99.7	103	104	102
PPOM Compounds, micrograms				
Benz(c)phenanthrene	2.2	0.85	0.9	1.2
7,12-Dimethylbenz(a)anthracene	2.3	0.85	0.55	0.3
Benz(a)pyrene + Benz(e)pyrene	--	0.30	12.0	0.009
Dibenz(a,h)pyrene	--	0.15	0.45	0.003
Dibenz(a,i)pyrene	--	0.15	0.45	0.003

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a) Dry standard cubic feet at 70°F, 29.92 in. Hg.
b) Dry standard cubic feet per minute at 70°F, 29.92 in. Hg.
c) Actual cubic feet per minute.

Table B-12. DATA SUMMARY FOR ASPHALT BLOWING - PLANT B

Run Number	Uncontrolled			Controlled		
	7	17	15	8	18	16
Date, 1974	5/10	5/14	5/14	5/10	5/14	5/14
Volume of Gas Sampled - DSCF[a]	113.099	34.923	106.449	201.265	30.068	183.41
Average Stack Temperature - °F	308	263	323	931	950	950
Percent Moisture by Volume - %	19.5	5.1	20.8	8.5	11.5	6.9
Stack Volumetric Flow Rate - DSCFM[a]	2212	3237	2613	10,272	10,207	10,319
Stack Volumetric Flow Rate - ACFM[c]	3987	4642	4869	29,322	30,402	29,241
Percent Isokinetic	113	83	107	103	97.1	97.7
Particulate - Filterable Catch						
milligrams				332.0	459.8	
gr/DSCF[d]				0.0255	0.236	
gr/ACF				0.0089	0.0792	
lb/hr				2.24	20.65	
Particulate - Total						
milligrams	82280.1	659.0	PPOM TEST	1298.4	832.8	PPOM TEST
gr/DSCF	11.227	0.291		0.0995	0.427	
gr/ACF	6.216	0.203		0.0349	0.143	
lb/hr	212.8	8.1		8.765	37.4	

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a) Dry standard cubic feet at 70°F, 29.92 in Hg.
b) Dry standard cubic feet per minute at 70°F, 29.92 in Hg.
c) Actual cubic feet per minute.
d) Grains per dry standard cubic foot.

Table B-13. PPOM EMISSIONS ASPHALT BLOWING - PLANT B
(net weight in sample, micrograms)

Compound	Test No. 15 Inlet 5/14/74	Test No. 16 Outlet 5/14/74
Benz(c)phenanthrene	57.0	4.1
7,12-Dimethylbenz(a)anthracene	6.6	--
Benz(a)pyrene + Benz(e)pyrene	42.0	1.3
Dibenz(a,h)pyrene	8.5	2.1
Dibenz(a,i)pyrene	8.5	2.1

Table B-14 GASEOUS EMISSION DATA - PLANT B

Test Number	CO ppm	Gaseous HC ppm
Saturator		
1 Inlet	2.3	800
2 Outlet	2.4	300
3 Inlet	6.8	970
4 Outlet	4.7	240
5 Inlet	36	180
6 Outlet	70	360
9 Inlet	15	310
10 Outlet	-	-
11 Inlet	192	340
12 Outlet	40	330
13 Inlet	-	-
14 Outlet	-	-
Asphalt Blowing		
7 Inlet	179	5900
8 Outlet	1018	410
15 Inlet	4	5400
16 Outlet	3	850
17 Inlet	3	3090
18 Outlet	4	1150

Table B-15. PROCESS DATA FOR ASPHALT BLOWING - PLANT C

Plant Plant C

Date 3/1/74

Location Cincinnati

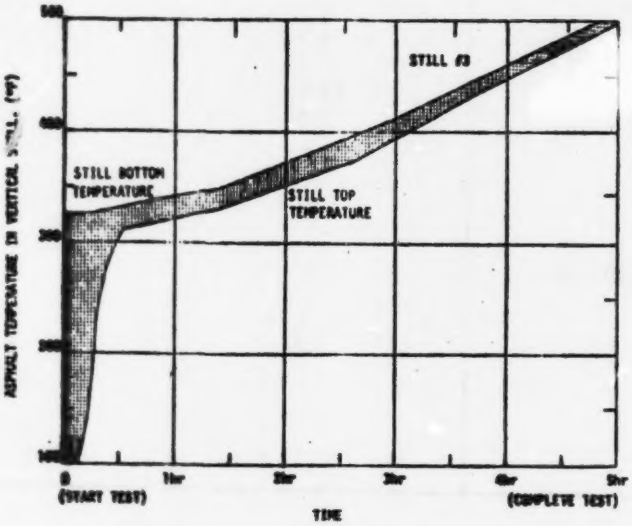
Observer DeWees

Still No. 3

Test #1

Quantity of Asphalt, gallons

Charged 3980 A oil @ 370; 10160 D oil @ 380 = 14140 gallons



Air Blowing Rate 1500 CFM @ 5 psi

Blowing Time, minutes 300 = 5 hours

Product Asphalt Coating ; Melt Point, °F 200-270

Afterburner - U.I.P. Eclipse Burner Model 42 FI-capacity 15 million BTU/hour.

Fuel Rate - could not determine (firebox at 1200 °F)
Inlet Temp., °F 180
Outlet Temp., °F 740

No Visible Emissions

Table B-15. (continued). PROCESS DATA FOR ASPHALT BLOWING - PLANT C

Plant Plant C

Date 3/5/74

Location Cincinnati

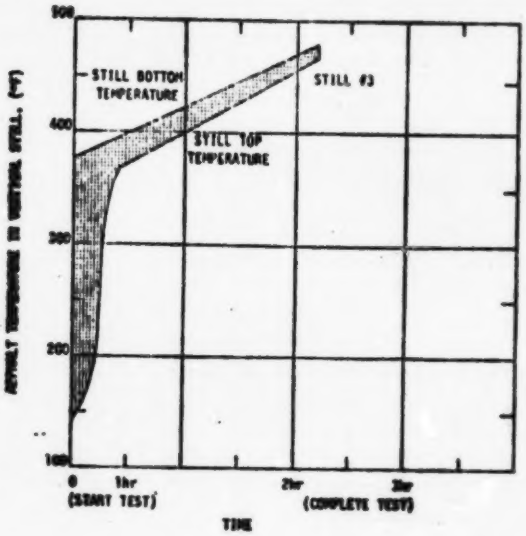
Observer DeWees

Still No. 3

Test #2

Quantity of Asphalt, gallons

Charged 3980 A oil @ 370; 10160 D oil @ 380 = 14140 gallons



Air Blowing Rate 1500 CFM @ 5 psi

Blowing Time, minutes 133 = 2.22 hours

Product Asphalt Saturant; Melt Point, °F 130

Afterburner - U.I.P. Eclipse Burner Model 42 FI-capacity 15 million BTU/hour.

Fuel Rate - could not determine (firebox at 1200 °F)
Inlet Temp., °F 160-240
Outlet Temp., °F 660-700

No Visible Emissions

Table B-15. (continued). PROCESS DATA FOR ASPHALT BLOWING - PLANT C

Plant Plant C

Date 3/6/74

Location Cincinnati

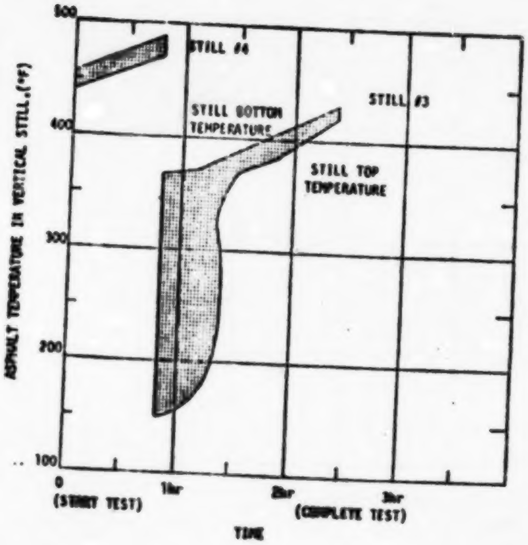
Observer DeWees

Still No. 4, 3

Test #3

Quantity of Asphalt, gallons

Charged 3980 A oil and 10160 D oil #4(for 40min.); 13500 A oil #3
Average charge blown = 13,700 gallons



Air Blowing Rate 1500 CFM @ 5 psi

Blowing Time, minutes 127 = 2.1 hours

Product Asphalt Saturant; Melt Point, °F 130

Afterburner - U.I.P. Eclipse Burner Model 42 FI-capacity 15 million BTU/hour.

Fuel Rate - could not determine (firebox at 1200 °F)
Inlet Temp., °F 225-180
Outlet Temp., °F 705

No Visible Emissions

Table B-15. (continued). PROCESS DATA FOR ASPHALT BLOWING - PLANT C

Plant Plant C

Date 4/5/74

Location Cincinnati

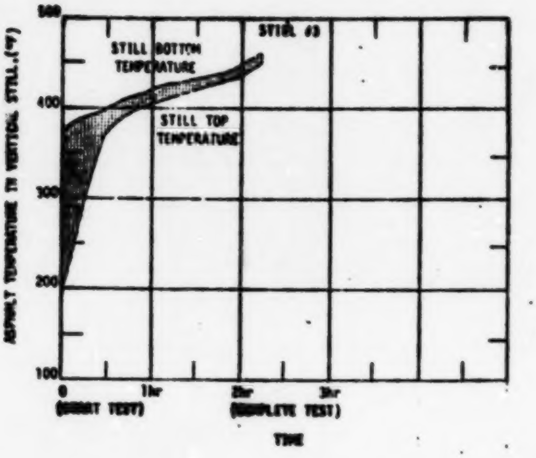
Observer DeWees

Still No. 3

Test #4

Quantity of Asphalt, gallons

Charged 3980 A oil @ 370; 10160 D oil @ 380 = 14140 gallons



Air Blowing Rate 1500 CFM @ 5 psi

Blowing Time, minutes 135 = 2.25 hours

Product Asphalt Coating ; Melt Point, °F 200-270

Afterburner - U.I.P. Eclipse Burner Model 42 FI-capacity 15 million BTU/hour.

Fuel Rate - could not determine (firebox at 1200 °F)
Inlet Temp., °F 170
Outlet Temp., °F 550

No Visible Emissions

Table B-16. DATA SUMMARY FOR ASPHALT BLOWING - PLANT C

Run Number	Uncontrolled				Controlled			
	1	2	3	4	1	2	3	4
Date, 1974	3/1	3/5	3/6	4/5	3/1	3/5	3/6	4/5
Volume of Gas Sampled - DSCF[a]	121.208	74.982	79.853	85.572	219.889	87.762	89.480	106.373
Average Stack Temperature - °F	211	206	202	169	736	696	705	544
Percent Moisture by Volume	17.4	16.9	18.2	14.3	7.0	7.9	8.6	5.9
Stack Volumetric Flow Rate - DSCFM[b]	2341	1962	2072	2313	10334	9750	9551	12030
Stack Volumetric Flow Rate - ACFM[c]	3623	3004	3210	3328	25159	23580	23291	24450
Percent Isokinetic	114	110	116	109	95.8	96.2	100.1	94.9
Particulate - Filterable Catch								
milligrams					286.2	36.1	32.4	
gr/DSCF[a]					0.020	.0063	0.0056	
gr/ACF					0.0083	.0026	0.0023	
lb/hr					1.78	0.53	0.457	
Particulate - Total								
milligrams	27979	7221.7	10669	PPOM TEST	1765.4	131.5	143.0	PPOM TEST
gr/DSCF	3.56	1.49	2.06		0.124	0.023	0.247	
gr/ACF	2.31	0.967	1.33		0.051	.0096	0.101	
lb/hr	71.5	25.0	36.6		10.97	1.93	2.02	

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a) Dry standard cubic feet at 70°F, 29.92 in Hg.
b) Dry standard cubic feet per minute at 70°F, 29.92 in Hg.
c) Actual cubic feet per minute.
d) Grains per dry standard cubic foot.

Table B-17. PPOM EMISSIONS ASPHALT BLOWING - PLANT C
(net weight in sample, micrograms)

Compound	Test 4 Inlet 4/5/74	Test 4 Outlet 4/5/74
Benz(c)phenanthrene	18	0.3
7,12-Dimethylbenz (a)anthracene	11	8.5
Benz(e)pyrene	0.4	3.1
Benz(a)pyrene	1.0	1.2
3-Methylcholanthrene		0.865
Dibenz(a,h)pyrene		0.07
Dibenz(a,i)pyrene		0.07

Table B-18. GASEOUS EMISSION DATA - PLANT C

Test Number	CO ppm	Gaseous HC[a] ppm	Aldehydes[b] ppm	H_2S ppm
1 Inlet	358, 416		0.6, 14.2	
1 Outlet	497		3.65, 15.1	
2 Inlet	416, 428			<0.02
2 Outlet	416, 8933			
3 Inlet	532, 7669			0.7, 0.3
3 Outlet	3351, 9106			<0.02
4 Inlet	210	6733		0.1
4 Outlet	1436	656		-

a) Expressed as methane
b) Expressed as formaldehyde